Fishery Manuscript No. 18-02

Bottom Trawl Surveys for Tanner Crab in Lower Cook Inlet and Prince William Sound 1990–2015, with Harvest Strategy Recommendations for Prince William Sound

by

Dr. Kenneth J. Goldman

Mike Byerly

Joshua Mumm

Jan Rumble

and

Dr. Jie Zheng

February 2018

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY MANUSCRIPT NO. 18-02

BOTTOM TRAWL SURVEYS FOR TANNER CRAB IN LOWER COOK INLET AND PRINCE WILLIAM SOUND 1990–2015, WITH HARVEST STRATEGY RECOMMENDATIONS FOR PRINCE WILLIAM SOUND

by
Dr. Kenneth J. Goldman, Mike Byerly, Joshua Mumm, Jan Rumble
Alaska Department of Fish and Game, Division of Commercial Fisheries, Homer
and
Dr. Jie Zheng
Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

February 2018

The Fishery Manuscript Series was established in 1987 by the Division of Sport Fish for the publication of technically oriented results of several years' work undertaken on a project to address common objectives, provide an overview of work undertaken through multiple projects to address specific research or management goal(s), or new and/or highly technical methods, and became a joint divisional series in 2004 with the Division of Commercial Fisheries. Fishery Manuscripts are intended for fishery and other technical professionals. Fishery Manuscripts are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/. This publication has undergone editorial and peer review.

Dr. Kenneth J. Goldman, Mike Byerly, Joshua Mumm, Jan Rumble,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
3298 Douglas Place, Homer, AK 99603, USA

and

Dr. Jie Zheng
Alaska Department of Fish and Game, Division of Commercial Fisheries,
PO Box 115526, Juneau, AK 99811, USA

This document should be cited as follows:
Goldman, K. J., M. Byerly, J. Mumm, J. Rumble, and J. Zheng. 2018. Bottom trawl surveys for Tanner crab in Lower Cook Inlet and Prince William Sound 1990–2015, with harvest strategy recommendations for Prince William Sound. Alaska Department of Fish and Game, Fishery Manuscript 18-02, Anchorage.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF APPENDICES (Continued)

ABSTRACT

This report summarizes bottom trawl survey data used to assess Tanner crab *Chionoecetes bairdi* abundance within the Alaska Department of Fish and Game's Central Region. Trawl surveys replaced pot surveys as the primary method of assessing Tanner crab in Central Region in the early 1990s. Data for the Central Region were collected from 2 management districts in the Lower Cook Inlet Management Area: 1) the Southern District (1990–2013), and 2) the Kamishak Bay and Barren Islands Districts (1990–2012). Data were also collected from the Prince William Sound Management Area (1991–2015). Since 1993 in the Southern District, and 1990 in the Kamishak Bay and Barren Islands Districts, the estimated abundance of legal male Tanner crab has not exceeded the minimum stock size threshold defined in regulation that is necessary to open a commercial fishery (Alaska Administrative Code 5 AAC 35.408). Bottom trawl survey methods have changed through the history of the survey and those changes are documented in this report. Abundance trends of legal and sublegal male and female Tanner crab are also described along with trends in recruitment. Analysis and harvest strategy recommendations to create a management plan for commercial and noncommercial Tanner crab fisheries in the Prince William Sound Management Area are presented.

Key words: Tanner crab, *Chionoecetes bairdi*, abundance, trawl survey, harvest strategy, Cook Inlet, Prince William Sound

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) has been conducting bottom trawl surveys for Tanner crab, *Chionoecetes bairdi*, in the lower Cook Inlet Management Area (CIMA) and Prince William Sound Management Area (PWSMA) of the Central Region since 1990 and 1991, respectively (Kimker 1996; Bechtol 2001; Bechtol 2005; Rumble et al. 2014; Figure 1). Data from these surveys are used to develop Tanner crab abundance estimates, monitor population trends, and set guideline harvest levels for commercial and noncommercial fisheries (Rumble et al. 2014).

Prior to 1992, ADF&G conducted pot surveys for Tanner crab and red king crab (*Paralithodes camtschaticus*) that began in CIMA in 1975 and PWSMA in 1977. These surveys provided an index of abundance (catch per unit effort (CPUE)) relative to that of the commercial fishery, were used to estimate the relative stock condition, and were used to set guideline harvest levels for commercial and noncommercial fisheries. Since 1992, assessment of Tanner crab has been conducted solely by trawl surveys. Pot surveys are still used as an index of abundance in other areas of Alaska, mostly in areas with untrawlable habitat.

The switch from pot to trawl surveys occurred because 1) abundance could be estimated with a trawl using area swept methods, 2) a trawl is less size selective than pots, and 3) a trawl is less susceptible to gear saturation (Bechtol et al. 2002). At the time of this method change, trawl surveys were also used by the National Marine Fisheries Service (NMFS) in the Bering Sea, and by ADF&G Westward Region, to determine stock abundance levels and annual harvests of Tanner and king crabs (Jackson 1990).

Bottom trawl surveys were conducted at 2 locations within CIMA and 1 within PWSMA. These management areas contain several management districts (Figure 1). One of the CIMA surveys occurred in Kachemak Bay, which lies completely within the Southern District (SD); that survey, data, and results will be referenced throughout this report as the SD survey. The other CIMA survey occurred in Kamishak Bay, which lies mostly within the Kamishak Bay District, but a small proportion also occurs within the Barren Islands District; that survey, data, and results will be referenced in this report as the KBBI survey. The PWSMA survey has stations in the Northern, Hinchinbrook, and Western Districts but those data are not separated by districts for analysis; that survey, data, and results will be referenced in this report as the PWSMA survey.

This report documents and summarizes trawl survey Tanner crab catch for the entire time series of each survey location and presents temporal population trends for the entire history of the trawl survey.

There is currently a harvest strategy for Tanner crab commercial and noncommercial fisheries in CIMA, but there is no management plan and harvest strategy for Tanner crab fisheries in the PWSMA. According to 5 AAC 35.310, fishing seasons for the PWSMA and commercial harvest of Tanner crab in PWSMA are closed until the Alaska Board of Fisheries adopts and publishes a harvest strategy. Historically, the Prince William Sound Tanner crab fishery had been managed under a size, sex, and season (3S) policy: harvesting males only equal to or greater than 5.3 inches and fishing only during January 15–March 30 (Rumble et al. 2014). Due to low survey abundance and poor fishery performance, the commercial fishery has been closed since 1990. In order to develop a harvest strategy for PWSMA, an analysis of historical fishery and survey data was conducted and recommendations are presented in this report.

OBJECTIVES

The objectives of this report are as follows:

1. Document methodological changes that have occurred in Central Region trawl surveys from 1990 to 2015;
2. Estimate relative annual abundance of female, pre-recruit male and legal male Tanner crab from trawl surveys in the SD, KBBI District, and PWSMA; and
3. Develop a harvest strategy for creation of a management plan for commercial and non-commercial Tanner crab fisheries in the PWSMA Management Area.

METHODS

SURVEY AREAS AND STATION GRIDS

The extents of all Central Region survey areas were based on historical pot survey areas and commercial harvest information. Those areas with very limited probability of crab catch were not included (Kimker 1991; Kimker and Trowbridge 1992). All survey areas were divided up into a station grid. Station sizes were initially based on the dimensions of Westward Region trawl survey stations, where bay stations were 6.25 nmi^2 and ocean stations 25 nmi^2. This gave the SD and PWSMA grids a nominal station size of 6.25 nmi^2 and the KBBI grid a nominal station area of 25 nmi^2 (Kimker 1991; Kimker and Trowbridge 1992). The configuration of survey grids has evolved for all areas in response to trawlable habitat, survey catch history, and efforts to improve efficiency and to reduce variance in abundance estimate (Appendices A and C). Each of the 3 areas has "core" stations that are sampled to estimate abundance. The number and size of core stations in each area have changed throughout the time series, which can lead to difficulty interpreting temporal abundance trends. All core stations in this report were standardized in number, spatial location, and size. For this reason, statistics and abundance estimates in this report may differ from previous reports (Bechtol 1999; Bechtol 2001; Bechtol 2005).

Southern District

The general location of the historical SD survey extends from Bear Cove in the inner part of Kachemak Bay west to 152°W. The initial survey grid developed in 1990 (SD1990), was composed of 22 stations (6.25 nmi^2; Figure 2). Station size and shape varied based on an

irregular coastline and depth. Depths shallower than 10 fa were excluded to reduce potential gear loss and better represent Tanner and red king crab habitat (Bechtol 2005). In 1992, station boundaries were revised to isolate a deep trough (>50 fa) located between Gull Island and Barabara Point with typically greater crab densities. The 1992 grid was used from 1992 to 2007. Starting in 2008, the 6 westernmost stations were eliminated due to historically low crab catches. The 2008 survey grid (SD2008) was used in 2008 and 2009.

In 2011, the SD survey grid was further refined in an attempt to reduce the variance of abundance estimates. Reducing individual tow length from 1.0 nmi to 0.5 nmi allowed the number of stations surveyed to be doubled. At the same time, interior and exterior grid boundaries were refined using high-resolution bathymetry recently acquired using multi-beam sonar. The shoreward boundaries of the 2011 grid (SD2011) were delineated using either depth or slope. The 10 fa northern survey boundary contour line for waters inside of the Homer Spit and the 20 fa northern survey boundary contour line for waters outside of the Homer Spit were updated as better bathymetry became available, which resulted in minor adjustments to the previous grids (Figure 2). The southern boundary was the 5 degree isocline east of the Homer spit and 50 fa contour to the west, with slopes steeper than 5 degrees considered untrawlable and the 50 fa contour coincided with the previous grid boundary. The northwest corner boundary was the 400 m buffer around a subsea fiber optic cable. One ancillary station (station 139) was retained outside of these bounds near Seldovia, primarily for groundfish sampling. Interior station borders were drawn according to ADF&G staff feedback with the following objectives: 1) increasing sampling density, 2) maintaining spatial continuity with previous station design and tow locations, and 3) minimizing variation in station size. Two types of untrawlable area were removed from the survey grid used to select tow paths, but not from the expansion area (81.23 nmi^2) used to calculate abundance estimates. This untrawlable habitat area included 2 subsea communication cable corridors and also several steep areas where the slope calculated from an 8 m digital elevation model was greater than 5 degrees. The SD2011 grid was used from 2011 to 2013.

Kamishak Bay and Barren Islands Districts

The general location of the KBBI survey extends east to 152°40′W and south of 59°40′N (Figure 3). As in the SD, depths less than 10 fa were excluded. The KBBI grid has evolved over time. In the KBBI Districts, stations along the margins of the grid which were previously not regularly surveyed were eliminated (Figure 3).

The grid used from 1990 to 1996 (KBBI1990) was comprised of 48 stations. In 1997, station 47 was split into 2 stations (471 and 472) to isolate a trench greater than 50 fa, and station 70 was eliminated. The 1997 grid (KBBI997) was used in 1997 and 1998. In 1999, the extra-large irregular nearshore stations were either reduced in size to the standard graticule (stations 23, 31, and 63) or eliminated (station 40). Also in 1999, stations were re-evaluated with respect to the 10 fa shoreward boundary, resulting in a small reduction in the size of stations 58 and 63. The 1999 grid (KBBI1999) was used from 1999 to 2006.

In 2007, 16 stations that were not regularly sampled were eliminated from the outer margins of the grid (Figure 3). The goal of this modification was to reduce the variance of abundance estimates by increasing sampling in the area of greatest crab density and to reduce interannual bias associated with stations (Appendix A2). It also provided a standardized area for the survey, which included all core stations from all years. Other changes to achieve this goal included

eliminating station 472, the 50 fa trench; trimming station 471 to only north of the trench; and trimming the southern row of stations (68 and 69) to the management area boundary (the latitude of Cape Douglas). The remaining 31 stations made up the 2007 grid (KBBI2007), which was used in 2007, 2010 and 2012. KBBI2007 also defines the core stations used to calculate the population estimates in this report. The expansion area for these population estimates was the sum of the 31 stations in KBBI2007 (771.86 nmi^2).

Prince William Sound Management Area

The core PWSMA stations were in the Northern, Hinchinbrook, and Western Districts of PWSMA, which includes Port Fidalgo, Orca Bay, and the North Montague area from Smith Island to Green Island (Figure 4). These core areas were surveyed every year of the survey and were the only stations used to calculate abundance estimates. In 2008, 2 core stations (113 and 114) were added in the North Montague area, and 1 in Port Fidalgo (station 29). The expansion area used to calculate the PSWMA abundance estimates was the sum of the 43 core stations (249.60 nmi^2). The core stations include 24 in Orca Bay, 5 in Port Fidalgo, and 14 in the North Montague area (Figure 4). Depths shallower than 50 fa were excluded to reduce gear damage and to better represent king and Tanner crab habitat (Bechtol 1999).

In addition to these consistently sampled core areas, a variety of ancillary stations have been sporadically sampled throughout the greater PWSMA over the survey's history. These ancillary stations were located near Kayak Island, in the Port Valdez area, Johnstone Bay, and Puget Bay (Figure 4; Appendix F). Some of the ancillary stations were surveyed to explore areas of historically high crab catches in the commercial fishery and pot survey, notably the 100 fa trench west of Kayak Island, the 100 fa trench south of Montague Island, and the southern Montague Strait area (Figure 4 and Appendix C). Other ancillary stations were sampled to improve the survey's ability to assess walleye Pollock *Gadus chalcogramma*, and skates for a developing fishery.

Sampling design

A fixed station sampling design was utilized for all surveys, however a simple random sampling estimator was used to estimate CPUE and population size when the fixed stations were comprised of all core stations, or as many as could be sampled in a given survey. An exception to this started in 2007 in the KBBI Districts when a random selection of 24 of the 31 core stations was initiated. In many years, poor weather conditions prevented all the KBBI core stations from being sampled. To minimize the bias from selectively choosing which stations to sample while in the field, a smaller number of randomly selected core stations were selected before the survey. This allowed for days when inclement weather inhibited or prevented trawling. The tow location within a station was decided by the captain. The captain drove within the station, observing the vessel's down sounder, and selected a location with minimal slope and rocky features that was large enough to complete a tow. Tow locations were typically near each other from year to year, but not overlapping.

Target tow length for all survey areas was 1.0 nmi at an average tow speed of 2.5 nm per hour. One exception to this was that in 2011 the SD tow length was reduced to 0.5 nmi (Appendix A). Tow length and speed can be influenced by factors such as sea conditions, seafloor sediment type such as mud, hang-ups on rocks or other obstructions, or capturing derelict pot gear and other objects such as large woody debris. During tow events, the captain monitored tow speed, engine

RPMs, and the trawl monitoring systems (TMS) to determine if a tow needed to be terminated early. Tows that were less than half the target length were discarded and the tow was repeated.

A 3:1 scope (trawl warp length to water depth) was used from 1990 to 2008, after which the NMFS RACE Gulf of Alaska scope tables were used (Stauffer 2004). The captain recorded the start position of each tow at the time the trawl warps were out at the required distance, and end position at the time the trawl warps started to be retrieved. Tow length was recorded from the GPS or navigation program. Following a survey, start and end tow positions were plotted in GIS and the lengths were calculated. If the difference between the 2 tow lengths was less than 10%, then the GIS position became the assigned tow length. If the GIS tow length was greater than 10%, then it was assumed a position was recorded incorrectly, and the captain's tow length became the assigned tow length.

Survey gear

The trawl surveys used a 400 mesh Eastern otter trawl, with a 23.8 m headrope and a 29.9 m footrope.[1] Mesh sizes were 10.2 cm in the wings and body, 8.9 cm in the intermediate, and 3.3 cm in the codend liner. The otter trawl was fished with 363 kg Nor'Eastern Astoria V trawl doors measuring 1.5 m by 1.8 m. The net opening was designed to be 2.7 m high and 12.2 m wide. The net has been modified twice since the inception of the surveys. The first modification was between the 1990 and 1991 surveys and involved rehanging the net, which altered the drop chain to prevent the net from digging into the substrate and occasionally collapsing (Kimker 1991). The second modification involved changing the headrope length. A 21.3 m headrope was used on the net from 1990 to 1999. Following discussions with NMFS RACE Division staff, the trawl was modified to use a longer 23.8 m headrope (Appendix A). This came following the suggestion that a longer headrope would allow the footrope to fish tighter to the bottom (Bechtol et al. 2005).

Over the course of these surveys, various sensors, cameras, and ancillary sampling equipment have been deployed either on the trawl or at station locations: temperature recorder, temperature depth recorder (TDR), bottom contact sensor (BCS), Netmind Trawl Mensuration System (TMS), video camera system deployed from the headrope to observe the capture process, and conductivity temperature depth (CTD) casts done at station locations. These sensors provided either environmental data that may be used for analyses of catch data or measurement data for post processing catch effort. Additionally, the TMS has been used to provide real time data on gear performance. The system includes wing sensors that were attached to the ends of the headrope, a headline sensor attached at the center of the headrope, a hydrophone deployed off the starboard side of the vessel, and a software program for data acquisition and display. The wing sensors measured the opening of the net and the headline sensor measured the height of the headrope off the seafloor. The system provided feedback to the Captain about net performance, so that adjustments could be made to maintain fishing performance or to avoid net damage. The TMS was first used in the 2010 KBBI survey and has been used on most surveys since.

Catch sampling

Upon retrieval of the trawl, the codend was weighed to the nearest 0.5 kg with a 4,535 or 5,000 kg capacity hanging electronic scale. The catch was emptied into a checker bin and the codend

[1] Product names used in this report are included for scientific completeness but do not constitute a product endorsement.

was reweighed. The catch weight was calculated by subtracting the weight of the empty codend from the initial codend weight (Appendix A).

The first tier of the catch sampling was to remove the primary target species (Table 1). Prior to 2010, this included all Tanner crab. Beginning in 2011, pre-recruit 4 Tanner crab (small crab) were removed from the primary target species list and were sampled with the remaining catch. Tanner crab were sorted by sex along with the other primary target species, placed into baskets, and weighed. Weighing was performed with hanging scales (to the nearest 0.5 kg) or on a motion compensated digital platform scale (to the nearest 0.01 kg) beginning in 2011.

Subsampling occurred if there were a lot of Tanner crab captured in the trawl. If there were less than 2 baskets of Tanner crab for a given sex, then biological data were collected from all of the crab; otherwise, biological data were collected from 2 baskets and the remaining crab were counted and discarded overboard. Retained crab were measured for carapace width (CW) to the nearest 0.1 mm and classified by shell condition (soft, new, old, or very old). Starting in 2009, chela height measurements were also collected for male Tanner crab with a CW greater than 50 mm to assess maturity status (Tamone et al. 2007). Female Tanner crab maturity was collected for mature females and clutch fullness, clutch condition, and egg development were assessed. Other primary target species were counted and biological data were collected on a species by species basis.

The remaining catch was either whole sampled or subsampled. If the remaining catch was smaller than two 22.7 kg (50 lb) fish baskets, the whole sample was processed; otherwise, a subsample was taken. If the remaining catch was very large (filled the checker bin above the first row), then three 22.7 kg fish baskets of catch were removed for a subsample; otherwise, a 2-basket subsample was taken. The rest of the catch was discarded overboard.

The remaining whole or subsample was sorted to species and sex for Tanner crab or the lowest taxonomic group and weighed in aggregate. If the sample was less than 2 kg, it was weighed to the nearest 0.001 kg, using either a hanging spring scale (1990–2010) or motion compensated bench scale (beginning in 2011). Otherwise, the sample was weighed on either of the hanging electronic scales to the nearest 0.5 kg or on a motion compensated digital platform scale to the nearest 0.01 kg (beginning in 2011). All Tanner crab were counted and measured for CW, maturity, and shell condition. All other species were counted and additional biological data were collected on secondary target species.

SURVEY DATA ANALYSIS

Crab CW was classified into size groups for pre-recruits and recruits based on estimated "age" from previous observations of Cook Inlet crab (Table 2). For analysis purposes, soft-shell and new-shell crab were pooled into a single new-shell category, whereas old-shell and very old-shell crab were pooled into a single old-shell category.

For each tow, Tanner crab catch was the summation of various parts of the on-deck sampling process. For each sex, the catch for each size group (c_i) for sample tow (i) was calculated by:

$$C_i = tc_i + sc_i + \frac{(tw_i - t_i - s_i)sc_i}{s_i}, \quad (1)$$

where:

tw_i = the weight of the catch in sample tow (i),

t_i = the weight of the primary target species in sample tow (i),

s_i = the weight of the subsample species in sample tow (i),

tc_i = the count of primary target sampled Tanner crab for each size group in sample tow (i), and

sc_i = the count of subsampled Tanner crab for each size group in sample tow (i).

The Tanner crab abundance estimates derived from surveys are based on area-swept calculations (Gunderson 1993; Sokal and Rohlf 1995). Mean catch per nautical mile ($\bar{c}$) by size group (sg) of crab, variance (s^2), and 95% confidence interval (CI) within an area was calculated by:

$$\bar{c}(sg) = \frac{\sum_{i=1}^{n} \frac{c_i}{l_i}}{n}, \tag{2}$$

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{c_i}{l_i} - \bar{c}\right)^2, \tag{3}$$

$$Var(\bar{c}) = \left(\frac{N-n}{N}\right)\frac{s^2}{n}, \text{ and} \tag{4}$$

$$CI = \pm t_{n-1}\sqrt{Var(\bar{c})}, \tag{5}$$

where:

c_i = the catch of a species size group, either as abundance or weight, in sample tow (i),

l_i = the distance towed in nautical miles for sample tow (i),

n = the number of standardized 1.0 or 0.5 nmi tows, and

N = the number of total possible tows in the survey area (total survey area / area of a standardized tow [i.e. 1.0 nmi or 0.5 nmi x (40'/6076')]).

An estimate of the surveyed population ($\hat{P}$) was calculated by expanding $\bar{c}$ over the surveyed area as:

$$\hat{P} = \left(\frac{6{,}076}{40}\right)A\bar{c}, \tag{6}$$

where:

6,076 = the length, in feet, of a nautical mile,

40 = the estimated width of the trawl opening in feet, and

A = standardized survey area (nmi^2).

Variance of the surveyed population was estimated by:

$$Var\left(\hat{P}\right)=\left(\frac{6{,}076}{40}A\right)^2 Var(\bar{c})\,. \tag{7}$$

HARVEST STRATEGY DEVELOPMENT FOR PRINCE WILLIAM SOUND TANNER CRAB

We have developed a harvest strategy for PWSMA Tanner crab. Harvest strategies for Tanner crab stocks in Alaska vary across the state (Bishop et al. 2011 and Table 3). These harvest strategies consist of 3 components:

1. A biomass or abundance threshold,
2. Mature harvest rates, and
3. Legal harvest rates or legal harvest rate cap.

Legal size and pre-recruit range determination

Legal sizes are typically 1 or 2 molts above male mature sizes (Donaldson and Donaldson 1992; Table 4). Therefore, the first step to determine the legal size was to study the sizes at maturity for male Tanner crab. Male CW and chela height data collected during the trawl surveys from 2007 to 2014 were analyzed with program MATURE (Somerton 1981), which separates immature and mature male Tanner crab. MATURE was used to iteratively fit 2 straight lines to log-transformed CW and chela height data: the upper line for large-clawed crab (mature crab) and the lower line for small-clawed crab (immature crab). First, it fit 2 straight lines to known small-clawed and known large-clawed crab at 2 ends of the data set, then extended the lines into the middle region of overlap by assigning points to the closest line, and then iteratively re-estimated the lines and reassigned data points until no points switched lines. The average of these 2 lines was used as a dividing line between the mature and immature crab groups (Figure 5). Estimated proportions of male maturity by size were used to derive sizes at maturity for male crab.

The current legal size is 135 mm CW, or 5.3 inches with spines, but because of information on terminal molt in PWSMA, data were modeled to see if a change to the minimum legal size was warranted. Based on the average legal-to-mature male abundance ratio of 22.6% from the 1991–2015 trawl survey data, when there was no commercial fishery, only a small proportion of males would reach the current legal size. With terminal molt, such a legal size limit would result in a large majority of males unable to reach legal size for a fishery to target. As such, the main reason for modeling these data was to examine legal size and determine if a change was warranted. Pre-recruit size ranges or categories have traditionally been used to summarize male crab abundance in Alaska (Rumble et al. 2014; Spalinger 2015). This helped summarize a large data set and provide information for projecting future recruitment into legal abundance. However, with a terminal molt stock, it was difficult to use for the projection because pre-recruits were not a predictor of future legal abundance. Tagging data would help to estimate

growth increments per molt, but tagging data were not available for PWSMA Tanner crab. We used growth increments per molt from other Tanner crab stocks to develop pre-recruit ranges for PWSMA Tanner crab. Growth increments per molt for male Tanner crab were available for Kodiak, Cook Inlet, and Southeast Alaska stocks (Table 5). Kodiak data are the oldest and have been applied to many stocks including Kodiak, Cook Inlet, and Southeast Alaska to define pre-recruits and recruit ranges (Table 4). Later, growth data from Southeast Alaska were used to create pre-recruit and recruit ranges for Southeast Alaska Tanner crab stocks (Stone et al. 2003; Zheng et al. 2007). The size at 50% maturity was estimated to be about 113 mm CW, based on the directed output of the program MATURE. However, a logistic curve was fit to the directed output and re-estimated size at 50% maturity at 108.3 mm CW (Figure 6). Based on the estimated size at maturity and catch sampling size composition data for PWSMA Tanner crab, the legal size (135 mm CW) was set lower than Kodiak and Cook Inlet Tanner crab (140 mm CW) by the Alaska Board of Fisheries in 1976 (Donaldson and Donaldson 1992). It appears that the pre-recruits and recruit ranges for PWSMA Tanner crab were adjusted accordingly, and the current ranges resemble the growth data from Cook Inlet (Paul and Paul 1996; Table 5).

Threshold and harvest rate determination

Ideally, computer simulations are used to evaluate alternative harvest strategies and determine thresholds and harvest rates. However, a model has not been developed for this stock; therefore computer simulations could not be performed. Harvest strategies from other Alaska Tanner crab stocks were used to develop thresholds and harvest rates for PWSMA Tanner crab.

The threshold is 50% of an average (a proxy of B_{msy} (Biomass at maximum sustainable yield)) of mature male or legal male abundance over a defined period for Tanner crab stocks in the Gulf of Alaska. Discrete harvest rates of mature males or molting mature males up to 20% are used for Southeast Alaska and Kodiak Tanner crab stocks (Table 3). Legal harvest rates of 15% and 25% are used for Cook Inlet Tanner crab stocks if abundance thresholds in regulation are met (5 AAC 35.408). The legal harvest rate caps are 25% in Cook Inlet, 30% in Kodiak, and 50% in Southeast Alaska stocks (Table 3). Harvest rate determination for the Eastern Bering Sea (EBS) Tanner crab stocks was more complicated than the Gulf of Alaska stocks (Zheng and Pengilly 2011). Based on these harvest rates, legal harvest rates from 0% to 25% or mature harvest rates from 0% to 20% could be used for the PWSMA Tanner crab stock.

The difficult task was how to define the B_{msy} proxy because although trawl survey abundance estimate are available from 1991 to 2015, the stock levels were very depressed during this period. In the Northern District and Hinchinbrook District, 25% of the average between 1991 and 2015 was about 5% of the average from 1977 to 2015. A commercial harvest strategy for the Valdez area was even more difficult to develop due to lack of data during high abundance periods. The historical pot survey data may be used to estimate abundance, but a model is needed to deal with those data. The raw pot survey data should be re-examined and requires further work. We used the approach of Bechtol et al. (2002) to convert the commercial catch to legal abundance. Inseason tagging data had an average returned rate of 46.5% during 1977/78–1981/1982 seasons (Donaldson 1986). Retained catches during 1974–1988 were converted to legal biomass (B) through dividing the mean harvest rate (h) of 46.5%:

$$B_t = C_t / h, \quad t = 1974\text{–}1988, \tag{8}$$

where t is year. The biomasses were then converted to legal abundances (L) by dividing the mean weights each year (w_t):

$$L_t = B_t / w_t \ . \tag{9}$$

The catch in the "Inside" area is assumed the same as the Northern District and Hinchinbrook District during 1974–1976 and the catches below 5.3 inches were excluded. Mean ratio (r) of mature to legal male abundances estimated from the trawl survey from 1991–1994 and 2007–2015 were used to estimate mature abundances (M) from legal abundances during 1974–1988:

$$M_t = L_t * r \ , \quad t = 1974\text{–}1988. \tag{10}$$

The period from 1995 to 2006 is excluded from the ratio estimation due to extremely low abundances. Because the retained catch before 1977 may include catch outside of the Northern District and Hinchinbrook District, average preferred legal abundance and mature male abundance during 1977–2015 are recommended as the B_{msy} proxy (ignoring the missing data points):

$$B_{msy} = mean\ of\ X_t \ , \quad t = 1977\text{–}2015 \ , \tag{11}$$

where X is either L_t or M_t, depending on the choice of legal or mature male abundance to represent the B_{msy} proxy.

RESULTS AND DISCUSSION

SOUTHERN DISTRICT

The SD survey began in 1990 following the closure of the commercial fishery in 1988. A sizable fishery had been prosecuted in the SD from the mid-1960s until the closure (Figure 7). A cyclic trend in the Tanner crab population is evident from the pot survey index time series. Relative abundance was high in the late 1970s, decreased in the early 1980s and increased again in the early to mid-1980s. The commercial fishery was reopened for 4 more years following a large increase in the index in 1990.

Legal males

Consistent with the rise in the 1990 pot survey index, the SD legal male Tanner crab population appeared to continue to increase as evident in the first 3 years of the trawl survey, but has generally been at lower levels following a decline that occurred from the peak abundance in 1992 (over 1 million, Figure 8). Besides that peak year and a few years in the early to mid-1990s, when legal male abundance estimates ranged between 300,000 and 500,000, legal male abundance has not exceeded 225,000 in the history of the survey (Table 6). Estimated legal male abundance was nearly 200,000 crab when the commercial fishery closed in 1994 (Table 6). Over the next few years, legal male abundance was between 100,000 and 275,000 crab. From 1999 through 2005, estimates of legal male Tanner crab declined precipitously from about 100,000 to just over 45,000. Numbers of legal males showed a substantial increase in 2006, to 224,000, but immediately began declining from 2007 to 2013 (Table 6). These trends were also observable in standardized CPUE data (Appendix B). The increase observed in 2006 enabled a noncommercial fishery to open between 2008 and 2012 as thresholds were met, but with the subsequent decline, threshold levels were not met and the noncommercial fisheries in Kachemak Bay closed in the 2011–2012 season (Rumble et al. 2014).

Sublegal males

Results on the abundance of sublegal males vary widely over the course of the SD survey (Table 6). Standardized CPUE shows several recruitment periods when pre-recruits can be tracked throughout the history of the survey (Figure 9). A few consecutive years of recruitment pulses are evident in the first year of the time series (1990) and can be tracked to legal size in the following 4 to 5 years. From 1990 through 1994, a small pulse of pre-recruits, starting at 80 mm CW, can be tracked growing into legal size in 1992 and 1993. A larger pre-recruit pulse, starting at about 40 mm CW, can be tracked between 2001 and 2004; however the results do not show this group of crab providing a substantial pulse of legal crab in the following years. The largest recruitment pulse recorded in the history of the SD survey (estimated to be over 4 million pre-recruit 4 crab; those <70 mm) can be seen starting in 2011 and going through 2013 (Figure 9; Appendix B). However, no surveys have been conducted since that time, so it is unknown whether this group of pre-recruits has matriculated through to a harvestable amount of legal crab. In addition to the standardized CPUE data where new and old shell crab are combined, abundance estimates for all male recruit categories with new- and old-shell Tanner crab were separated for pre-recruit 2 and larger crab (Appendix D).

Females

Female Tanner crab abundance in the SD showed similar trends to males. However, because the cohorts that make up juvenile and mature female Tanner crab abundance estimates are different than those for sublegal and legal males, male recruit classes must be summed over different classes to compare trends. Survey results for juvenile female abundance were relatively stable from 1990 through 2000 (Table 7). The abundance of juvenile females increased substantially in 2001 and 2002 before returning to previous levels. Starting in 2009, juvenile female abundance began to increase again and reached its highest levels in the history of the survey in 2011 and 2012, with estimates of over 4 million individuals (Table 7). Mature female abundance was reasonably stable between 1990 and 2003, after which, levels of abundance began to show large increases followed by large decreases, and on average has been ~50% higher for the 2004 to 2013 period than for the prior time period. The estimate of mature female abundance was at the highest level in the history of the survey in 2013 (Table 7; Appendix B). In addition to abundance information, biological data on clutch fullness was collected from female Tanner crab (Appendix E).

KAMISHAK AND BARREN ISLANDS DISTRICTS

Legal males

The KBBI Districts had a similar commercial harvest history to the SD (Figure 10). Pot survey index trends are also similar to those in the SD, but show a larger decline in relative abundance of legal male Tanner crab, with only a slight increase occurring in the mid-1980s. As in the SD, the commercial fishery was reopened following an increase in the pot survey index in 1989, with similar levels the following year. The first year of the trawl survey in the KBBI Districts was 1990 and had the highest estimated abundance of legal male Tanner crab in the trawl survey history.

The time series of legal male abundance in the KBBI Districts has shown a consistent decrease over the history of the survey, with episodic years of higher abundance (Figure 11 and Table 8). Abundance estimates dropped from almost 900,000 legal male Tanner crab in 1990 to just over

300,000 in 1995. The commercial fishery closed in 1992, when estimated abundance had decreased to just over 250,000. Legal male abundance estimates did increase to over 600,000 in 1996 and 1997, but dropped precipitously starting in 1998 and remained at low numbers through 2005. Driven by high recruitment in the early and mid-2000s, legal abundance increased to 508,000 crab in 2006 and 321,000 in 2010, though variation around these estimates was high (Table 8). The large survey estimates in 2006 and 2010 enabled a noncommercial fishery to open between 2008 and 2012; however, after that, the average number of legal male Tanner crab did not meet management threshold levels, so the noncommercial fisheries in Kamishak Bay closed in the 2011–2012 season (Rumble et al. 2014). In the last year of the survey (2012) no legal male Tanner crab were captured. These trends were also observable in standardized CPUE data (Appendix B).

Sublegal males

Recruitment patterns of pre-recruit 4 (<70 mm CW) Tanner crab in the KBBI Districts showed similar trends to that in the SD (Tables 6 and 8). Standardized CPUE shows several recruitment periods when pre-recruits can be tracked throughout the history of the survey (Figure 12). In 1990 and 1991, a pulse of pre-recruits, starting at about 110 mm CW, can be tracked through time to legal size. From 1994 through 1997, another pre-recruit class, starting at about 90 mm CW, can be tracked with a small amount reaching legal size. In 2001 and 2002, the largest group of pre-recruit classes in the history of the survey, starting at about 30 mm CW, in 2001 can be tracked through 2006 when there was a pulse of recruitment to legal size (Figure 12). The second largest group of pre-recruits in the history of the survey occurred in 2005. This group of pre-recruits, starting at about 40 mm CW, tracks into 2006, but does not appear in the 2007 survey and no surveys were conducted in 2008 or 2009. However, there was a large recruitment to legal size in 2010 (when the survey estimated over 320,000 legal males) which appears to be a result of the 2005 recruit pulse (Figure 12; Appendix B). A small pulse of recruitment was observed in the 2012 survey, coincident with recruitment in SD. Recruitment of pre-recruit 4 crab was observed in the SD in 2011 and 2013, but because no surveys were conducted in the KBBI in those years, it is unknown if similar events occurred there. In addition to the standardized CPUE data, where new and old shell crab are combined, abundance estimates for all male recruit categories with new- and old-shell Tanner crab were separated for pre-recruit 2 and larger crab (Appendix D).

Females

Abundance of mature female Tanner crab in the KBBI Districts is generally characterized by 2 periods of high abundance (Table 9; Appendix B). The first periods occurred in 1993 and 1994, when abundance was estimated at over 1.6 million crab. The second period occurred from 2002 to 2004 and 2006, when abundance ranged from 1.2 million to 2.3 million crab. Estimated abundance ranged from 5,000 to 660,000 mature Tanner crab in other years. High mature female abundance estimates in the 2000s were preceded by high recruitment of juvenile females ranging from 4.7 million to 8.7 million female crab. One pulse of recruitment in juvenile females was detected in the first year of the survey (1990) and probably contributed to high abundances of mature females in 1993 and 1994. Catches of mature females were highly variable in years of high estimated abundance. This, in combination with few stations having high catches contributed to the large confidence intervals around the estimates. In addition to abundance information, biological data on clutch fullness was collected from female Tanner crab (Appendix E).

PRINCE WILLIAM SOUND

Legal males

The PWSMA trawl survey began in 1991 following the last closure of the commercial fishery in 1988 (Figure 13). Although commercial Tanner crab fishing in PWSMA began in 1968, fishing in the Northern and Hinchinbrook Districts, which encompass the trawl survey area, did not begin until 1976. The pot survey index data for this same area shows similar periodicity to the CIMA surveys, though peaks in relative abundance appeared to occur a few years later. In addition, as in KBBI Districts, a similar, though more precipitous decline of legal male Tanner crab occurred through 1988. The fishery reopened for 3 more years starting in 1986, but was closed due to a large decline in the survey index. Though relative abundance increased in CIMA into 1990, it is unknown if the same occurred in the PWSMA because a legal male pot survey index is not available after 1988.

Estimated abundance of legal Tanner crab declined through the first years of the trawl survey, and remained low but returned to earlier levels or higher in more recent years (Figure 14). There was a large decrease in legal male abundance between 1993 and 1999, going from about 120,000 to just over 3,600. Legal male estimates showed a somewhat steady increase from 2001 through 2009, increasing to just over 43,000. The 2011 and 2013 surveys showed a large increase in legal male abundance and both surveys provided estimates of around 185,000; however the most recent 2 surveys in 2014 and 2015 have shown a decrease in numbers to about 135,000 and 103,000, respectively (Table 10). This places abundance estimates for legal males at the same level as the first few years of the survey, which began 2 years after the last commercial fishery in the PWSMA was prosecuted in 1989 (Rumble et al. 2014). These trends were also observable in standardized CPUE data (Appendix B).

Sublegal males

Though much of the PWSMA survey time series was on an every other year rotation, the recruitment trends of pre-recruit 4 Tanner crab for the PSWMA survey appear similar to those in the SD and KBBI surveys (Tables 6, 8, and 10). Standardized CPUE shows several recruitment periods when pre-recruits can be tracked throughout the history of the survey (Figure 15). Starting in 1990, a group of pre-recruit male crab, starting at about 40 mm CW, can be tracked through 1993 and 1994, leading to some reaching legal size. There was very little to no recruitment between 1995 and 2000. A small recruitment pulse of pre-recruit male crab, starting at about 30 mm CW in 2001, can be tracked through 2005, when it produced a small amount of legal males. In 2007 and 2009, another pulse of crab, starting at about 60 mm CW, can be tracked into 2011, 2012 and 2013, leading to the largest pulse of legal males observed in the survey (Figure 15; Table 10; Appendix B). Starting in 2013, the largest pulse of pre-recruit male crab observed in the history of the survey can be seen tracking into 2015; which was the last survey conducted. In addition to the standardized CPUE data, where new and old shell crab are combined, abundance estimates for all male recruit categories with new- and old-shell Tanner crab were separated for pre-recruit 2 and larger crab (Appendix D).

Females

Female Tanner crab abundance estimates in PWSMA have ranged from just over 130,000 in 1999 to just over 7 million in 2013 (Table 11). However, the 2013 estimate was contributed to by the largest number of juvenile females observed in the history of the survey, over 6 million.

Other than that single year spike in juvenile female abundance, estimates have ranged between 107,000 and 1.6 million, but were decreasing in 2015 towards the lower levels observed in the history of the survey (Table 11). Mature female abundance estimates decreased from about 850,000 in 1992 to fewer than 23,000 by 1999, which is the lowest level in the history of the survey. However, from 2000 through 2013, mature females abundance estimates steadily increased and were at the highest levels since the survey began (Table 11). Average abundance for the period 2001 to 2015 has been approximately 713,000, which is similar to levels at the beginning of the survey time series. Low but positive recruitment of juvenile females in 2001 and again from 2007 through 2014 has helped to maintain the relatively stable level of mature females since the early 2000s. In addition to abundance information, biological data on clutch fullness was collected from female Tanner crab (Appendix E).

HARVEST STRATEGY FOR PRINCE WILLIAM SOUND TANNER CRAB

We derived estimated catch, mature male, legal male, and molting mature male abundance for PWS Tanner crab (Tables 12 and 13). Molting mature males are defined as 100% new-shell mature males and 15% old shell mature males (Zheng and Pengilly 2011). Recommended alternative harvest strategies for PWSMA Tanner crab are described below.

Size at maturity, recruits and pre-recruit ranges

The relationship between the log of CW and log of chela height denotes the separation of immature and mature males (Figure 5). Generally, immature and mature males are well separated in the plot. The size at 50% maturity was estimated to be about 113 mm CW based on the directed output of the program MATURE. A logistic curve was fit to the directed output, resulting in a smooth estimate of size at 50% maturity at a slightly lower value of 108.3 mm CW (Figure 6). The size at 50% maturity for male Tanner crab in the PWSMA is similar to other Tanner crab stocks in Alaska (Table 4). Because the current size at maturity is defined as 113 mm CW, which was estimated using the PWSMA Tanner crab data more than 40 years ago (Donaldson and Donaldson 1992), and is similar to our estimates, we recommend continuing to use 113 mm and keeping the current size categories for maturity, recruits, and pre-recruit classes in PWSMA (Table 2).

Legal size

Based on the male maturity size, the legal size should be redefined to a smaller size similar to that implemented in the EBS Tanner crab harvest strategy, status quo 135 mm (5.3 inch) will be redefined as the preferred legal size and 113 mm (4.4 inch) as the legal size (Zheng and Pengilly 2011). The preferred legal size is used to achieve thresholds and set total allowable catch (TAC), and catch can be retained as long as it is above the legal size. All retained catch are counted towards the TAC. For terminal molt stocks, this approach would result in lower bycatches, thus a higher yield over a long term, and lower harvest rates for the faster growing, larger males.

Commercial fishery threshold for Northern District and Hinchinbrook District

There are 2 commercial fishing scenarios presented below. Using 50% of average abundance during 1977–2015 (B_{msy} proxy), the threshold is 200,000 preferred legal males for scenario 1 and 860,000 mature males for scenario 2. The recommendation is as follows: to prevent opening a fishery prematurely, abundance should be above the threshold for 2 consecutive years to open

the fishery if the fishery has been closed for more than 2 years consecutively just before the opening.

Noncommercial fishery threshold for Northern District and Hinchinbrook District

A much lower threshold should be used to provide for sustainable noncommercial fisheries. One of thresholds for the noncommercial fishery in the SD area is 5% of the B_{msy} proxy. Based on that, we recommend 5% of the B_{msy} proxy is used for noncommercial fisheries threshold for PWSMA Tanner crab. To make the noncommercial fishery more stable, we recommend the noncommercial fishery be opened or closed based on the average of 3 year abundances. For example, if the average of 3-year preferred legal abundances is below the threshold, then the noncommercial fishery would be closed. Using 5% of average abundance (B_{msy} proxy) during 1977–2015, or 85,800 mature males or 20,300 preferred legal males. We recommend that the noncommercial fishery be closed only when the average of 3-year preferred legal or mature male abundances is below the threshold.

Commercial fishery threshold for Valdez area

A commercial harvest strategy for the Valdez area of PWSMA was more difficult to develop due to the lack of data during high abundance periods. However 2 options exist, 1) open and close the fishery based on the threshold of the Northern and Hinchinbrook Districts or 2) set the threshold as 120% of the highest trawl survey abundance during 1999–2015, because the fishery has been closed during this period. Because the abundance in this area has been so low, it would not be prudent to prosecute a commercial fishery independently from a commercial fishery being prosecuted in other districts in PWSMA. As such, the first option would be preferable to ensure population protection and fishery sustainability. For the noncommercial fishery threshold, we recommend 25% of the average abundance from the trawl surveys during 1999–2015, either mature male or preferred legal abundance. We recommend option 1, that any commercial fishery in this area open or close the same time as the Northern District and Hinchinbrook District. No commercial fishery should be prosecuted in this area otherwise.

Noncommercial fishery threshold for Valdez area

Using 25% of average abundance during 1999–2015, or 18,516 mature males or 9,350 preferred legal males. Our recommendation is that the noncommercial fishery will be closed only when the average of 3-year preferred legal or mature male abundances is below the threshold.

Two scenarios for harvest rates for Northern District and Hinchinbrook District

1. Legal harvest rates applied to preferred legal abundance are as follows:

   15%: if the preferred legal males are equal to or greater than the threshold, but less than 0.75 B_{msy} proxy,

   20%: if the preferred legal males are equal to or greater than the 0.75 B_{msy} proxy but less than the B_{msy} proxy, and

   25%: if the preferred legal males are equal to or greater than the B_{msy} proxy.

B_{msy} proxy is 410,000 preferred legal males.

2. Molting mature harvest rates are as follows:

   10%: if mature males are equal to or greater than the threshold, but less than the0.75 B_{msy} proxy,

   15%: if mature males are equal to or greater than the 0.75 B_{msy} proxy but less than B_{msy} proxy, and

   20%: if mature males are equal to or greater than the B_{msy} proxy.

B_{msy} proxy is 1.72 million mature males.

Legal harvest rates are converted as follows:

Molting mature harvest rate molting mature male abundance/preferred legal male abundance, and the legal harvest rate cap is 30%.

Molting mature males are defined as 100% new-shell mature males and 15% old-shell mature males.

Harvest strategy recommendation

We recommend scenario 1 as the harvest strategy for Prince William Sound Tanner crab. Scenario 1 is simpler and uses less data than scenario 2. More importantly, it allows mature crab to participate in reproduction at least once before being subject to harvest.

Survey and data summary

The strength in a time series of survey estimates is the ability to detect abundance trends in a population that are biologically meaningful. The variability in estimates needs to be small in order to detect changes. For all 3 areas, stations have been added, station boundaries adjusted, and expansion areas refined throughout the years, with the goal of reducing bias and variability. Though changes have occurred, the core stations for each survey, which are represented in the current station grids, have remained. In the case of the SD survey, these core stations have been further divided to increase the number of samples, but spatially, the sampling effort has remained the same. All historical estimates in this report were made using the current expansion areas. Maintaining this continuity throughout the time series is critically important so that any changes observed between or among years are not due to a change in sampling design. These surveys provide and index of abundance that is adequate for tracking changes in abundance within the survey areas and for management purposes, and probably represents changes to the total population because it is unlikely that any changes would only occur within the survey area.

By using a fixed station sampling design rather than a random design, survey estimates are probably biased to some extent. However, having stations fixed reduces the spatial variability among years and increases the likelihood of detecting temporal differences.

Being a fishery-independent survey conducted off research vessels, sampling methodology and procedures can be more consistent. With the exception of the addition of a subsampling procedure for smaller crab, the catch sampling methodology has been consistent over the years reported. Improvements have largely been the introduction of additional sampling, such as the collection of chela height measurements. The same is true for the manner in which tows are conducted with respect to factors such as tow speed, scope, and deployment and retrieval.

Despite the desire to maintain consistency in all facets of the surveys, there are some changes the reader should keep in mind when interpreting the results. Starting in 2012, the R/V *Solstice* started to participate in the surveys which may have introduced a vessel effect. Though both vessels share similar displacement and horsepower, any possible vessel effect remains unknown. The introduction of the longer 78′ headrope may also have introduced an effect by changing the capture efficiency of the trawl net. Unfortunately, there was not an opportunity to conduct a comparative study and it was decided that if the switch was made, it should be done earlier in the time series. If there was a change in gear efficiency, it probably was an increase in capture efficiency because the objective of the longer headrope was to help the footrope tend to the bottom better.

We assumed a constant net opening of 40′ at the footrope for all area-swept calculations. Though this is the designed width of the net, it does vary depending on many factors. It is assumed that these factors average out and the constant is representative within a year and consistent over the time series. We also assumed 100% of crabs encountered by the footrope were captured (i.e. gear efficiency equals 1). When measured directly, capture efficiency can deviate from this theoretical value due to alterations in behavior or changes in gear performance (Guderson 1993) and for Tanner crab, be dependent on body size and sex (Somerton and Otto 1999). One important effect of trawl efficiency is escapement beneath the footrope (Dickson 1993). Escapement can increase as footrope distance off bottom increases (Weinberg et al. 2004). Trawl bottom contact can be a function of tow speed (Somerton and Weinberg 2001; Weinberg et al. 2002), door spread (Von Szalay and Somerton 1995), or trawl geometry (Weinberg and Somerton 2004). The TMS was added to the trawl to monitor and help maintain the shape of the net and the BCS was added to measure footrope contact and time on bottom. Data collected from these devices are helpful in understanding the dynamics of the trawl and may be incorporated into CPUE estimates, but would be difficult to extrapolate those finding to prior surveys when the instruments were not used.

Recruit classes have not tracked very well over the years, however when placed into 5 mm bins, recruits can be tracked fairly well over time (Figures 9, 12 and 15). It is hoped that the new pre-recruit class categories derived from recent analyses of PWSMA, SD, and KBBI Tanner crab data will provide better tracking of recruit classes after ADF&G staff have re-categorized all historical survey data into new pre-recruit bins.

ACKNOWLEDGEMENTS

Many ADF&G staff and volunteers have assisted in the conduction of bottom trawl surveys over the years. We thank Captains Mark Hottmann, Sid Wolford, Dave Branshaw, Dave Anderson, and Ted Jewell. Great thanks go to Richard Gustafson who was responsible for most of the gear preparation, maintenance and repair of trawl nets, and deck operations during surveys for many years. We thank Bill Bechtol who was responsible for coordinating this research for many years and was involved at all levels from data collection in the field to reporting and setting management goals. Great thanks to Margaret Spahn who was responsible for coordinating the migration of historical survey data into a relational database. We thank the many ADF&G staff and volunteers for their help over the years: Chuck Adams, James Brady, Ryjil Christianson, Lance Craig, John Crofts, Sharon Delsack, Willy Dunne, Thomas Farrugia, Carmen Field, Conrad Field, Robert Fusco, Nell Gustafson, James Gustafson, Luke Hottmann, Susan Inglis, Dave Knight, Morris Lambdin, Joe Loboy, James Meesis, Carla Milburn, Daisy Morton, Megan

Murphy, Edward Otis, Jeff Regnart, Elisa Russ, Chris Russ, Martin Schuster, Shareef Siddeek, Sigfus Sigurdsson, Charles Stock, Karen Swartzbart, Sherry Tamone, Renn Tolman, Charlie Trowbridge, Maria Wessel, James Wiese, Xinxian Zhang and Frank Zellin. We also thank Jack Erickson and an anonymous peer reviewer for comments that greatly improved the report.

REFERENCES CITED

Bechtol, W. R. 1999. A bottom trawl survey for crabs and groundfish in the Prince William Sound management area, 16-26 August 1997. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A99-24, Anchorage.

Bechtol, W. R. 2005. A bottom trawl survey for crabs and groundfish in the Southern, Kamishak Bay, and Barren Islands Districts of the Cook Inlet Management Area, 20–25 June and 10–17 July 2000. Alaska Department of Fish and Game, Fishery Data Series No. 05-40, Anchorage.

Bechtol, W. R. 2001. A bottom trawl survey for crabs and groundfish in the Southern, Kamishak, and Barren Islands Districts of the Cook Inlet Management Area, 19–23 July and 16–23 August 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A01-05, Anchorage.

Bechtol, W. R., C. E. Trowbridge, and N. Szarzi. 2002. Tanner and king crabs in the Cook Inlet Management Area: stock status and harvest strategies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A02-07, Anchorage.

Bishop, G., J. Zheng, L. M. Slater, K. Spalinger, and R. Gustafson. 2011. The current status of the fisheries for *Chionoecetes* spp. (DECAPODA, OREGONIIDAE) in Alaska waters. Pages 109–126 [*In*] New Frontiers in Crustacean Biology. Koninklijke Brill NV, Leiden.

Dickson, W. 1993. Estimation of the capture efficiency of trawl gear. I: development of a theoretical model. Fisheries Research 16:239-253.

Donaldson, W. 1986. Tanner crab tagging and index survey 1986. Alaska Department of Fish and Game, Division of Commercial Fisheries, Prince William Sound Management Area Data Report 86-16. Cordova, Alaska.

Donaldson, W. E., and W. K. Donaldson. 1992. A review of the history and justification for size limits in Alaska king, Tanner, and snow crab fisheries. Alaska Department of Fish and Game, Fisheries Research Bulletin No. 92-02, Juneau, Alaska.

Donaldson, W. E., R. T. Cooney, and J. R. Hilsinger. 1981. Growth, age, and size at maturity of Tanner crab, *Chionoecetes bairdi* in the Northern Gulf of Alaska. Crustaceana 40:286–302.

Gunderson, D. R. 1993. Surveys of fisheries resources. John Wiley, New York, NY.

Kimker, A. 1991. Cook Inlet king and Tanner crab index of abundance survey, June 11-29, 1990. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2H90-17, Homer.

Kimker, A. 1996. Cook Inlet Area annual shellfish management report, 1995–96. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 2A96-30, Anchorage.

Kimker, A., and C. Trowbridge. 1992. A bottom trawl survey for crabs in the Prince William Sound Management Area, August 20-30, 1991. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A92-14, Anchorage.

Paul, A. J., and J. M. Paul. 1996. Changes in carapace and chela measurements of functionally mature male held in the laboratory. Pages 445–450 [*In*] High Latitude Crabs: Biology, Management, and Economics. Alaska Sea Grant College Program Report No. 96-02, University of Alaska Fairbanks.

Rumble J., M. Wessel, E. Russ, K. J. Goldman, R. L. Gustafson, and C. Russ. 2014. Cook Inlet and Prince William Sound area management report for Tanner and king crab fisheries through 2013. Alaska Department of Fish and Game, Fishery Management Report No. 14-08, Anchorage.

REFERENCES CITED (Continued)

Somerton, D. A. 1981. Life history and population dynamics of two species of Tanner crab, *Chionoecetes bairdi* and *C. opilio*, in the eastern Bering Sea with implications for the management of the commercial harvest. Ph.D. dissertation, University of Washington, Seattle.

Somerton, D. A., and R. S. Otto. 1999. Net efficiency of a survey trawl for snow crab, *Chionoecetes opilio*, and Tanner crab, *C bairdi*. Fisheries Bulletin 97:617-625.

Somerton, D. A., and K. L. Weinberg. 2001. The effect of speed through the water on footrope contact of a survey trawl. Fisheries Research 53:17-24.

Stauffer, G. 2004. NOAA protocols for groundfish bottom trawl surveys of the nation's fishery resources. U.S. Department of Commerce, NOAA Technical Memo NMFS-F/SPO-65.

Sokal, R. R., and F. J. Rohlf. 1995. Biometry: the principles and practice of statistics in biological research, third edition. Department of Ecology and Evolution. W.H. Freeman and Co.

Spalinger, K. 2015. Bottom trawl survey of crab and groundfish: Kodiak, Chignik, South Peninsula, and Eastern Aleutian Management Districts, 2014. Alaska Department of Fish and Game, Fishery Management Report No. 15-27, Anchorage.

Stone, R. P., M. M. Masuda, and J. E. Clark. 2003. Growth of male Tanner crab *Chionoecetes bairdi* in a Southeast Alaska Estuary. Alaska Fishery Research Bulletin 10(2):137–148.

Tamone, S. L., S. J. Taggart, A. G. Andrews, J. Mondragon, and J. K. Nielsen. 2007. The relationship between circulating ecdysteroids and chela allometry in male Tanner crabs: Evidence for a terminal molt in the Genus *Chionoecetes*. Journal of Crustacean Biology 27:635–642.

Von Szalay, P. G., and D. A. Somerton. 1995. The effect of net spread on the capture efficiency of a demersal survey trawl used in the eastern Bering Sea. Fisheries Research 74:86-95.

Weinberg, K. L., and D. A. Somerton. 2004. Capture probability of a survey trawl for red king crab (*Paralithodes camtschaticus*). Fisheries Bulletin 102:740-749.

Weinberg, K. L., R. S. Otto, and D. A. Somerton. 2004. Capture probability of a survey trawl for red king crab (*Paralithodes camtschaticus*). Fisheries Bulletin 102:740−749.

Weinberg, K. L., D. A. Somerton, P. T. Munro. 2002. The effect of trawl speed on the footrope capture efficiency of a survey trawl. Fisheries Research 58:303-313.

Zheng, J., and D. Pengilly. 2011. Overview of proposed harvest strategy and minimum size limits for Bering Sea District Tanner crab. Alaska Department of Fish and Game, Special Publication No. 11-02, Anchorage.

Zheng, J., J. M. Rumble, and G. H. Bishop. 2007. Estimating Southeast Alaska Tanner crab abundance using pot survey and commercial catch data. Alaska Fisheries Research Bulletin 12(2):227–242.

TABLES AND FIGURES

Table 1.–Target species and species groups for Central Region large-mesh trawl surveys.

Common name		Scientific name
Invertebrates	Brown box crab	*Lopholithodes foraminatus*
	Dungeness crab	*Cancer magister*
	golden king crab	*Lithodes aequispina*
	magister armhook squid	*Berryteuthis magister*
	north Pacific octopus	*Enteroctopus dofleini*
	red king crab	*Paralithodes camtschaticus*
	sunflower seastar	*Pycnopodia helianthoides*
	Tanner crab	*Chionoecetes bairdi*
	weathervane scallop	*Patinopecten caurinus*
Fishes	all rockfish species	Scorpaenidae
	all salmon species	Oncorhynchus
	all skate egg case	Rajidae
	all skate species	Rajidae
	Atka mackerel	*Pleurogrammus monopterygius*
	giant wrymouth	*Cryptacanthodes giganteus*
	lingcod	*Ophiodon elongatus*
	Pacific cod	*Gadus macrocephalus*
	Pacific halibut	*Hippoglossus stenolepis*
	Pacific sleeper shark	*Somniosus pacificus*
	sablefish	*Anoplopoma fimbria*
	salmon shark	*Lamna ditropis*
	spiny dogfish	*Squalus suckleyi*
	Walleye pollock	*Gadus chalcogramma*
	Wolf eel	*Anarrhichthys ocellatus*
	Bering wolffish	*Anarhichas orientalis*

Table 2.–Male Tanner crab carapace width (mm) by recruit categories for the Cook Inlet and Prince William Sound Management Areas.

	Cook Inlet Southern, Kamishak Bay and Barren Islands Districts	Prince William Sound All Districts
Pre-recruit 4	<70	<73
Pre-recruit 3	70–91	73–92
Pre-recruit 2	92–114	93–112
Pre-recruit 1	115–139	113–134
Recruit	140–165	135–157
Post-recruit	>165	>157

Note: Cook Inlet legal size is >140 mm; Prince William Sound legal size is >135.

Table 3.–Comparison of current commercial Tanner crab harvest strategies in Alaska.

Region / District	Period for mean	Threshold	Exploitation rate	Legal exploitation rate cap
SE Alaska	1993–2002, MM	0.5 mean MM	0.05, 0.1, 0.15, 0.20 MM	0.5 LM
Cook Inlet				
Southern	1968–2001, LM	0.5 mean LM	0.15 LM or 0.25 LM if > mean LM	0.25 LM
Kamishak & B. Islands	1970–2001, LM	0.5 mean LM	0.15 LM or 0.25 LM if > mean LM	0.25 LM
Western area				
Kodiak	1973–1998, MM	0.5 mean MM	0.1 MMM, or 0.2 MMM if ≥ mean MMM	0.3 LM
Chignik	1974–1998, MM	0.5 mean MM	0.1 MMM, or 0.2 MMM if ≥ mean MMM	0.3 LM
South Peninsula	1974–2004, MM	0.5 mean MM	0.1 MMM, or 0.2 MMM if ≥ mean MMM	0.3 LM
East Aleutians	1990–2000, MM	0.5 mean MM	0.1 MMM, or 0.2 MMM if ≥ mean MMM	0.3 LM
E. Bering Sea	1975–2000, MMB, MFB	0.25 MMB & 0.4 MFB		

Source: Bishop et al. 2011.

Note: MM: mature male abundance, LM: legal male abundance, MMM: molting mature male abundance (100% new-shell and 15% old-shell), MMB: mature male biomass, MFB: mature female biomass.

Table 4.–Comparison of current size at maturity, legal size and pre-recruit stage of male Tanner crab in Alaska used for fishery management.

					Eastern Bering Sea	
	SE Alaska	PWSMA	Cook Inlet	Kodiak	166°W	166°E
Mature	111	113	–	115	103	113
Legal	140(5.5")	135(5.3")	140(5.5")	140(5.5")	127(5")	127(5")
Recruit	140–171	135–157	140–165	140–164	–	–
Pre-recruit 1	111–139	113–134	115–139	115–139	–	–
Pre-recruit 2	–	93–112	92–114	92–114	–	–
Pre-recruit 3	–	73–92	70–91	70–91	–	–

Note: Size measurement (carapace width in mm (and inches)) includes spines.

Table 5.–Comparison of mean growth increments per molt of male Tanner crab in Southeast Alaska (SEAK).

Pre-molt carapace width (mm)	SEAK	Cook Inlet	Kodiak
57.5	–	11.33	14.9
62.5	–	12.0	15.9
67.5	19.0	12.0	16.8
72.5	20.0	13.0	17.6
77.5	21.4	14.0	18.3
82.5	22.5	18. 7	19.8
87.5	24.2	18.4	20.3
92.5	26.0	21. 7	22.4
97.5	27.5	17.5	22.2
102.5	27.0	17.4	23.1
107.5	27.4	19.2	22.9
112.5	26.9	21.3	23.7
117.5	28.5	14.3	25.0
122.5	29.8	20.0	26.0
127.5	30.7	21.5	25.2
132.5	32.0	22.2	–
137.5	31.4	23.0	–
142.5	32.1	–	–

Sources: (Stone et al. 2003, n = 305), Cook Inlet (Paul and Paul 1996, n = 63), and Kodiak (Donaldson et al. 1981, n = 329).

Table 6.–Male Tanner crab abundance estimates from bottom trawl surveys in the Southern District, 1990–2013.

		No. sublegal males by pre-recruit size (CW)				Legal males			
Year	Tows	<70 mm	70–91 mm	92–114 mm	115–139 mm	≥140 mm	±CI	Total # of males	Total ±CI
1990	14	496,674	722,894	613,950	492,692	388,422	403,617	2,714,634	1,145,882
1991	15	293,894	277,640	802,800	848,159	499,815	226,608	2,722,308	879,693
1992	15	237,159	125,034	455,057	902,459	1,055,855	734,287	2,775,565	1,097,301
1993	16	578,321	89,958	135,248	325,507	518,498	254,074	1,647,532	430,628
1994	16	312,332	210,142	132,840	158,590	193,199	106,304	1,007,104	451,486
1995	16	356,090	389,839	565,725	506,325	278,365	296,245	2,096,344	1,299,465
1996	16	186,397	44,644	522,916	601,084	101,322	69,836	1,456,364	1,174,485
1997	16	171,929	123,219	287,722	325,897	143,111	80,729	1,051,879	323,965
1998	16	325,474	19,208	24,005	195,049	205,808	190,004	771,087	373,615
1999	16	911,483	1,160,291	697,642	200,663	104,282	91,894	3,074,360	2,743,906
2000	16	513,366	453,588	390,984	380,557	82,374	72,974	1,820,868	754,144
2001	16	1,619,958	655,741	319,106	392,469	96,951	61,266	3,084,224	1,995,590
2002	14	2,027,607	1,275,475	499,598	211,036	88,010	69,895	4,101,726	2,098,934
2003	16	1,228,442	1,188,614	710,246	288,894	48,717	52,980	3,464,914	1,726,501
2004	16	671,544	1,119,199	1,037,689	683,921	110,930	75,834	3,623,284	1,875,763
2005	15	1,043,700	185,975	186,987	347,339	45,676	41,786	1,809,679	1,083,062
2006	17	1,029,633	154,678	230,111	226,338	224,530	286,932	1,865,289	1,828,893
2007	16	339,466	92,716	176,167	373,061	162,504	238,989	1,143,914	1,252,423
2008	16	552,269	224,880	159,200	239,726	105,440	130,955	1,281,516	787,437
2009	15	1,000,556	643,343	852,512	554,785	143,882	141,993	3,195,079	2,338,396
2010									
2011	37	4,109,517	159,347	40,208	94,797	42,660	40,810	4,447,159	1,983,355
2012	37	2,031,199	2,532,088	188,265	57,085	20,512	20,105	4,829,149	1,796,356
2013	37	925,729	680,678	1,390,554	141,245	38,077	34,026	3,179,046	975,058

Note: No survey was conducted in 2010. CW is carapace width and CI is 95% Confidence Interval.

Table 7.–Female Tanner crab abundance estimates from bottom trawl surveys in the Southern District, 1990–2013.

	Juvenile		Mature		Total	
Year	Abundance	±CI	Abundance	±CI	Abundance	±CI
1990	986,132	435,566	437,762	471,302	1,423,894	597,299
1991	485,795	350,909	848,952	827,100	1,334,746	1,092,684
1992	287,743	188,991	748,755	908,911	1,036,498	914,538
1993	568,171	323,143	578,012	610,110	1,146,183	594,572
1994	643,345	524,200	384,757	329,104	1,028,103	697,829
1995	675,120	424,282	863,188	805,917	1,538,308	945,949
1996	223,512	145,814	506,237	533,304	729,750	589,474
1997	188,883	91,602	305,560	316,959	494,443	345,855
1998	399,268	303,830	78,481	155,168	477,749	320,493
1999	1,237,351	1,087,752	566,811	595,051	1,804,162	1,377,638
2000	692,520	549,354	250,751	301,589	943,271	592,957
2001	2,161,815	2,321,558	447,251	437,516	2,609,066	2,353,086
2002	2,750,107	1,524,651	435,209	410,903	3,185,316	1,718,798
2003	1,315,229	976,196	244,512	134,582	1,559,741	1,081,698
2004	1,244,052	618,088	1,888,886	2,164,265	3,132,939	2,526,689
2005	985,618	829,221	224,362	356,513	1,209,980	840,474
2006	937,529	1,319,050	29,068	36,427	966,597	1,325,638
2007	603,481	604,255	1,509,612	3,184,135	2,113,093	3,767,243
2008	575,419	341,259	230,828	310,804	806,247	404,396
2009	1,416,060	1,161,372	1,530,501	1,167,925	2,946,561	2,007,361
2010	NS					
2011	4,089,701	2,235,938	248,151	177,539	4,337,851	2,231,297
2012	4,637,663	2,188,235	662,344	451,927	5,300,007	2,527,127
2013	1,175,307	465,649	1,957,902	1,353,766	3,133,209	1,541,356

Note: NS is No Survey; CI is 95% Confidence Interval.

Table 8.–Male Tanner crab abundance estimates from bottom trawl surveys in the Kamishak and Barren Island Districts, 1990–2012.

		No. sublegal males by pre-recruit size (CW)				Legal males			
Year	Tows	<70 mm	70–91 mm	92–114 mm	115–139 mm	≥140 mm	±CI	Total # of males	Total ±CI
1990	24	2,343,010	415,444	1,248,429	3,521,907	878,119	908,963	8,406,909	5,347,618
1991	17	363,383	257,555	645,110	2,422,733	633,072	861,578	4,321,853	3,683,036
1992	25	290,117	650,387	690,579	1,633,143	255,690	261,499	3,519,915	2,627,080
1993	15	616,031	289,969	1,465,325	1,299,662	217,974	297,377	3,888,960	2,786,986
1994	17	343,382	1,494,026	2,794,670	2,745,826	313,137	248,129	7,691,041	6,782,889
1995	24	42,450	635,435	2,012,984	2,245,803	300,676	191,956	5,237,347	3,281,458
1996	18	1,092,813	255,392	1,036,060	3,705,260	653,725	854,499	6,743,250	4,360,052
1997	18	860,145	37,979	600,232	2,588,459	634,540	550,799	4,721,354	2,650,767
1998	22	440,213	47,759	88,982	467,926	155,707	130,260	1,200,587	758,395
1999	19	1,254,331	155,404	1,893,008	517,297	104,686	98,278	3,924,726	5,203,674
2000	24	685,432	67,668	74,983	209,916	18,906	18,248	1,056,905	601,950
2001	24	4,886,764	159,084	39,160	140,415	48,739	32,206	5,274,162	5,714,424
2002	19	8,344,733	4,933,368	2,206,800	211,513	36,244	41,245	15,732,658	17,351,538
2003	17	516,594	2,091,958	1,530,707	337,583	61,798	82,649	4,538,640	4,014,458
2004	22	559,643	2,940,237	4,039,863	630,002	15,991	18,263	8,185,736	4,298,470
2005	21	6,257,594	373,244	3,124,052	2,100,083	60,810	59,265	11,915,783	11,300,835
2006	27	2,488,298	1,818,579	2,226,190	2,387,932	508,114	358,459	9,429,112	4,346,765
2007	24	613,642	147,372	247,025	278,816	54,864	53,871	1,341,717	701,198
2008	NS								
2009	NS								
2010	23	142,366	111,766	425,216	813,496	321,871	489,159	1,819,863	2,625,747
2011	NS								
2012	23	972,054	271,082	750,123	98,449	0	0	2,091,708	2,022,469

Note: NS is no survey; CW is carapace width; and CI is 95% Confidence Interval.

Table 9.–Female Tanner crab abundance estimates from bottom trawl surveys in the Kamishak and Barren Island Districts, 1990–2012.

	Juvenile		Mature		Total	
Year	Abundance	±CI	Abundance	±CI	Abundance	±CI
1990	2,741,071	2,423,360	661,069	727,759	3,402,140	2,963,358
1991	485,382	301,555	138,581	172,967	623,962	422,262
1992	529,093	433,590	254,647	322,152	783,740	718,053
1993	806,903	837,524	1,658,317	2,295,012	2,465,220	2,491,195
1994	855,041	673,889	1,649,330	1,676,064	2,504,370	2,204,704
1995	265,255	213,756	643,871	630,247	909,126	715,131
1996	1,014,212	1,220,734	235,985	314,104	1,250,197	1,229,102
1997	360,957	379,264	127,440	98,510	488,397	386,641
1998	390,173	304,350	10,454	15,004	400,627	305,277
1999	1,262,254	2,050,170	66,687	94,350	1,328,941	2,045,100
2000	685,318	481,235	4,885	10,105	690,203	480,045
2001	4,763,296	5,126,156	106,567	149,720	4,869,864	5,239,724
2002	8,721,427	9,479,174	1,280,225	1,896,367	10,001,652	10,949,242
2003	1,185,493	1,659,076	2,345,611	2,632,721	3,531,104	4,187,076
2004	539,823	472,879	2,190,730	2,762,620	2,730,554	3,152,065
2005	6,605,240	10,617,867	297,507	287,639	6,902,747	10,712,637
2006	3,742,790	2,489,724	1,184,130	907,410	4,944,465	2,799,115
2007	529,240	399,965	43,967	50,172	573,207	404,781
2008	NS					
2009	NS					
2010	183,365	136,481	20,391	32,969	203,756	155,972
2011	NS					
2012	886,365	524,889	230,392	372,255	1,116,756	702,687

Note: NS is no survey; CW is carapace width; and CI is 95% Confidence Interval.

Table 10.–Male Tanner crab abundance estimates from bottom trawl surveys in Prince William Sound, 1991–2015.

		No. sublegal males by pre-recruit size (CW)				Legal males			
Year	Tows	<73 mm	73–92 mm	93–112 mm	113–134 mm	≥135 mm	±CI	Total # of males	Total ±CI
1991	29	832,376	697,768	326,658	275,497	134,820	106,043	2,267,119	1,420,647
1992	37	601,934	319,988	487,459	318,010	68,119	39,590	1,795,511	606,398
1993	38	470,946	118,931	226,671	266,073	121,184	39,588	1,203,805	433,640
1994	38	669,317	79,685	123,373	182,595	55,544	23,511	1,110,513	484,107
1995	32	294,093	41,317	71,749	100,786	24,820	15,535	532,765	171,825
1996		NS							
1997	39	209,713	55,957	51,115	34,283	11,336	11,048	362,403	158,018
1998		NS							
1999	40	116,969	7,717	27,531	16,792	3,677	3,574	172,686	64,516
2000		NS							
2001	40	1,364,121	407,171	223,047	59,143	6,626	6,655	2,060,109	784,610
2002		NS							
2003	40	495,341	113,424	195,928	94,758	15,882	17,969	915,333	360,036
2004		NS							
2005	40	279,702	80,563	142,569	117,450	28,940	25,743	649,224	291,641
2006		NS							
2007	32	747,359	201,817	219,781	225,888	17,749	14,290	1,412,595	423,048
2008		NS							
2009	43	1,009,676	509,029	256,459	337,161	43,836	30,505	2,156,161	883,720
2010		NS							
2011	43	984,555	403,755	537,706	574,852	186,422	87,727	2,687,291	1,732,997
2012		NS							
2013	43	5,986,794	1,024,721	429,215	322,264	184,993	74,780	7,947,986	2,332,125
2014	41	817,801	634,475	421,009	329,437	134,929	80,188	2,337,652	647,317
2015	43	611,044	466,331	609,544	302,250	102,789	46,797	2,091,958	882,128

Note: NS is no survey; CW is carapace width; and CI is 95% Confidence Interval.

Table 11.–Female Tanner crab abundance estimates from bottom trawl surveys in Prince William Sound, 1991–2015.

	Juvenile		Mature		Total	
Year	Abundance	±CI	Abundance	±CI	Abundance	±CI
1991	1,491,508	1,068,760	647,057	253,271	2,138,565	1,199,315
1992	667,192	195,130	859,829	389,374	1,527,021	455,774
1993	460,476	223,580	304,666	130,179	765,142	256,815
1994	700,447	481,601	223,479	107,325	923,926	506,303
1995	257,603	118,930	97,336	44,093	354,938	130,055
1996	NS					
1997	223,738	109,838	99,705	70,201	323,443	159,290
1998	NS					
1999	107,444	47,079	22,788	13,549	130,231	50,243
2000	NS					
2001	1,634,795	555,504	630,644	328,247	2,265,440	769,155
2002	NS					
2003	424,736	223,746	516,506	332,555	941,242	393,196
2004	NS					
2005	349,601	213,607	258,566	141,310	608,167	284,636
2006	NS					
2007	760,869	321,407	711,987	380,483	1,472,856	518,408
2008	NS					
2009	771,105	448,728	1,050,207	622,541	1,821,312	714,539
2010	NS					
2011	1,035,740	730,891	654,548	390,494	1,690,288	835,235
2012	NS					
2013	6,103,293	2,102,140	1,093,875	605,695	7,197,168	2,213,381
2014	1,011,592	373,670	811,606	380,555	1,823,198	500,306
2015	400,355	209,237	690,873	298,312	1,091,229	371,458

Note: NS is no survey and CI is 95% Confidence Interval.

Table 12.–Retained catch (in millions of pounds and million crab), estimated mature male, legal, molting mature male abundances (million crab) and projected catch for Tanner crab in Prince William Sound.

Year	Catch (lb)	Catch (*N*)	Mature males	Legal males	Molting mature males	Projected catch (w/scenario 1)	Projected catch (w/scenario 2)
1974	1.18	0.56	5.19	1.23	2.91	0.64	0.77
1975	0.66	0.31	2.92	0.69	1.63	0.36	0.43
1976	2.12	1.01	9.35	2.21	5.23	1.16	1.39
1977	1.55	0.74	6.84	1.62	3.83	0.85	1.02
1978	2.16	0.98	9.09	2.15	5.09	1.13	1.35
1979	1.36	0.65	6.00	1.42	3.36	0.74	0.89
1980	0.47	0.24	2.19	0.52	1.23	0.27	0.33
1981	0.96	0.46	4.26	1.01	2.39	0.53	0.63
1982	1.07	0.51	4.74	1.12	2.66	0.59	0.71
1983	0.50	0.24	2.22	0.53	1.24	0.28	0.33
1984–85	0.00	0.00					
1986	0.37	0.18	1.65	0.39	0.93	0.16	0.25
1987	0.37	0.18	1.66	0.39	0.93	0.16	0.25
1988	0.28	0.13	1.25	0.29	0.70	0.09	0.19
1989–90	0.00	0.00					
1991	0.00	0.00	0.41	0.13	0.17		
1992	0.00	0.00	0.39	0.07	0.20		
1993	0.00	0.00	0.39	0.12	0.22		
1994	0.00	0.00	0.24	0.06	0.06		
1995	0.00	0.00	0.13	0.02	0.02		
1997	0.00	0.00	0.05	0.01	0.02		
1998	0.00	0.00					
1999	0.00	0.00	0.02	0.00	0.00		
2000	0.00	0.00					
2001	0.00	0.00	0.07	0.01	0.04		
2002	0.00	0.00					
2003	0.00	0.00	0.11	0.02	0.05		
2004	0.00	0.00					
2005	0.00	0.00	0.15	0.03	0.08		
2006	0.00	0.00					
2007	0.00	0.00	0.24	0.02	0.14		
2008	0.00	0.00					
2009	0.00	0.00	0.38	0.04	0.29		
2010	0.00	0.00					
2011	0.00	0.00	0.76	0.19	0.55		
2012	0.00	0.00					
2013	0.00	0.00	0.51	0.18	0.24		
2014	0.00	0.00	0.46	0.13	0.28		
2015	0.00	0.00	0.41	0.10	0.31		

Table 13.–Retained catch, estimated mature male, legal and molting mature male abundances (number of crab) for Tanner crab in the Valdez area of the Prince William Sound Management Area.

Year	Catch (lb)	Catch (*N*)	Mature males(*N*)	Legal males (*N*)	Molting mat. males (*N*)
1977	60,814	27,251			
1978	12,880	5,451			
1979	0	0			
1980	11,886	5,507			
1981	6,450	2,798			
1982	3,078	1,536			
1983	5,570	2,785			
1984	0	0			
1985	0	0			
1986	25,470	12,402			
1987	0	0			
1988	1,753	877			
1989–1998	0	0			
1999	0	0	33,437	22,163	13,796
2000	0	0			
2001	0	0	38,842	25,852	5,826
2002	0	0			
2003	0	0			
2004	0	0			
2005	0	0	110,953	50,481	43,574
2006	0	0			
2007	0	0	75,395	21,654	43,732
2008	0	0			
2009	0	0	67,939	30,201	35,656
2000	0	0			
2011	0	0	147,231	86,682	105,177
2012	0	0			
2013	0	0	67,825	36,402	45,057
2014	0	0	55,560	31,741	25,299
2015	0	0	69,383	31,406	23,889

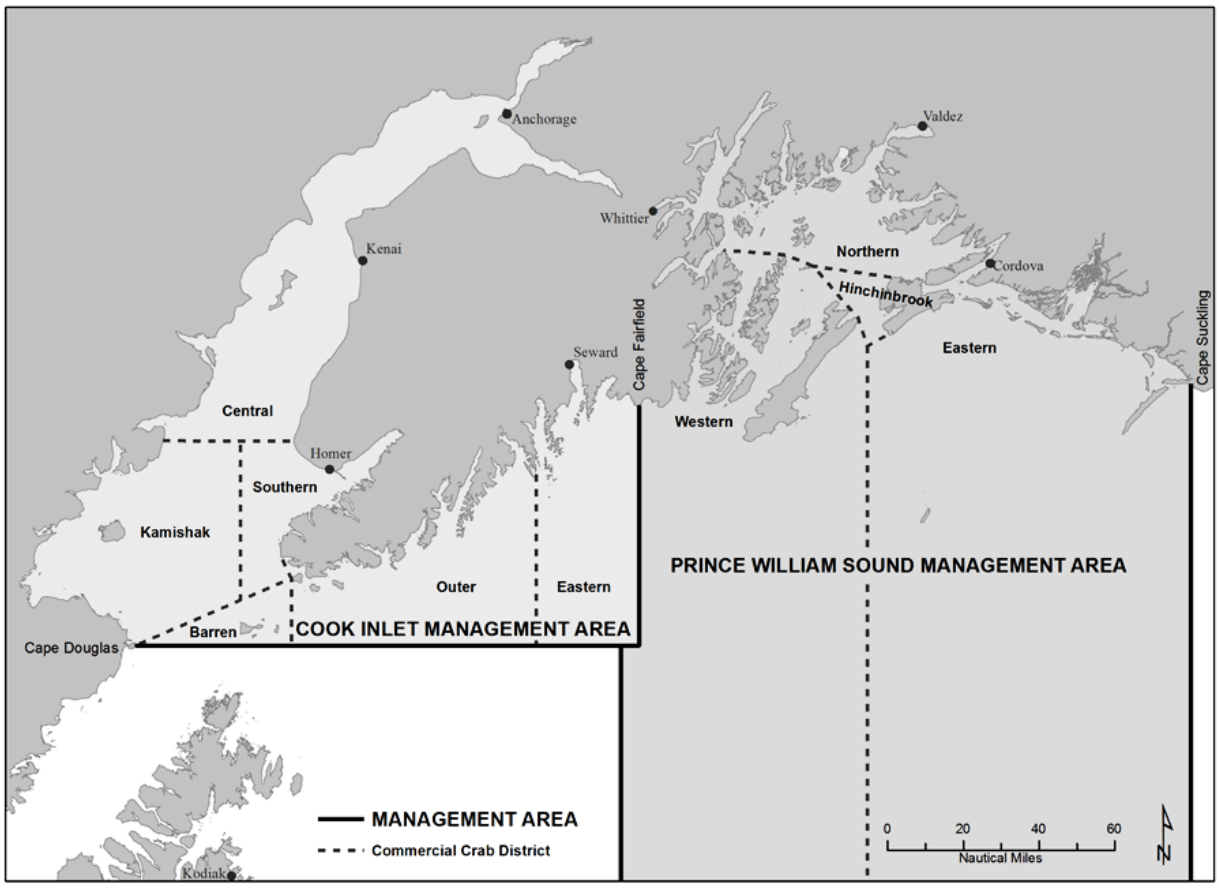


Figure 1.–Alaska Department of Fish and Game Central Region, Cook Inlet (Area H) and Prince William Sound (Area E) Management Areas.

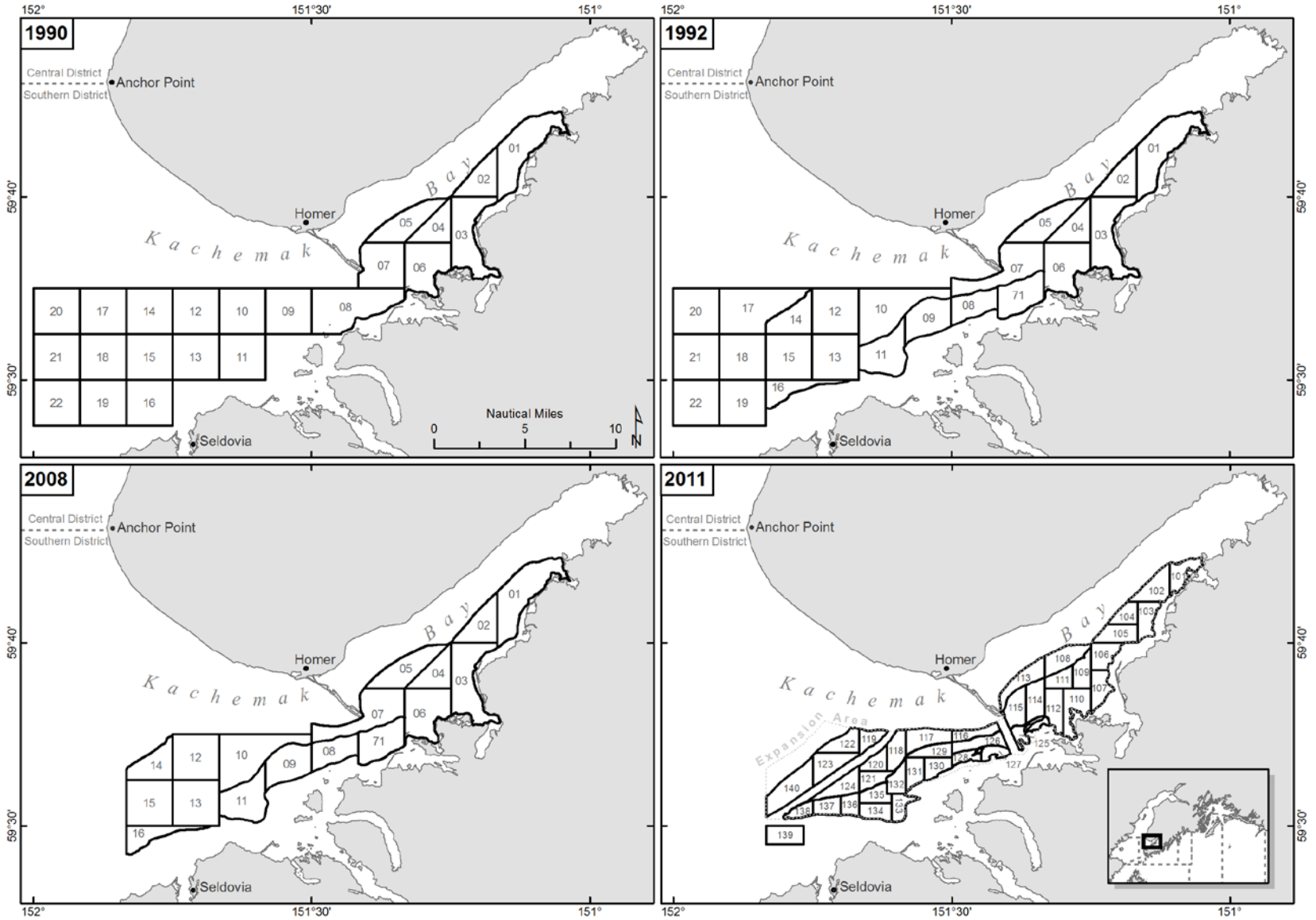


Figure 2.–Maps showing changes in Southern District bottom trawl survey grids.

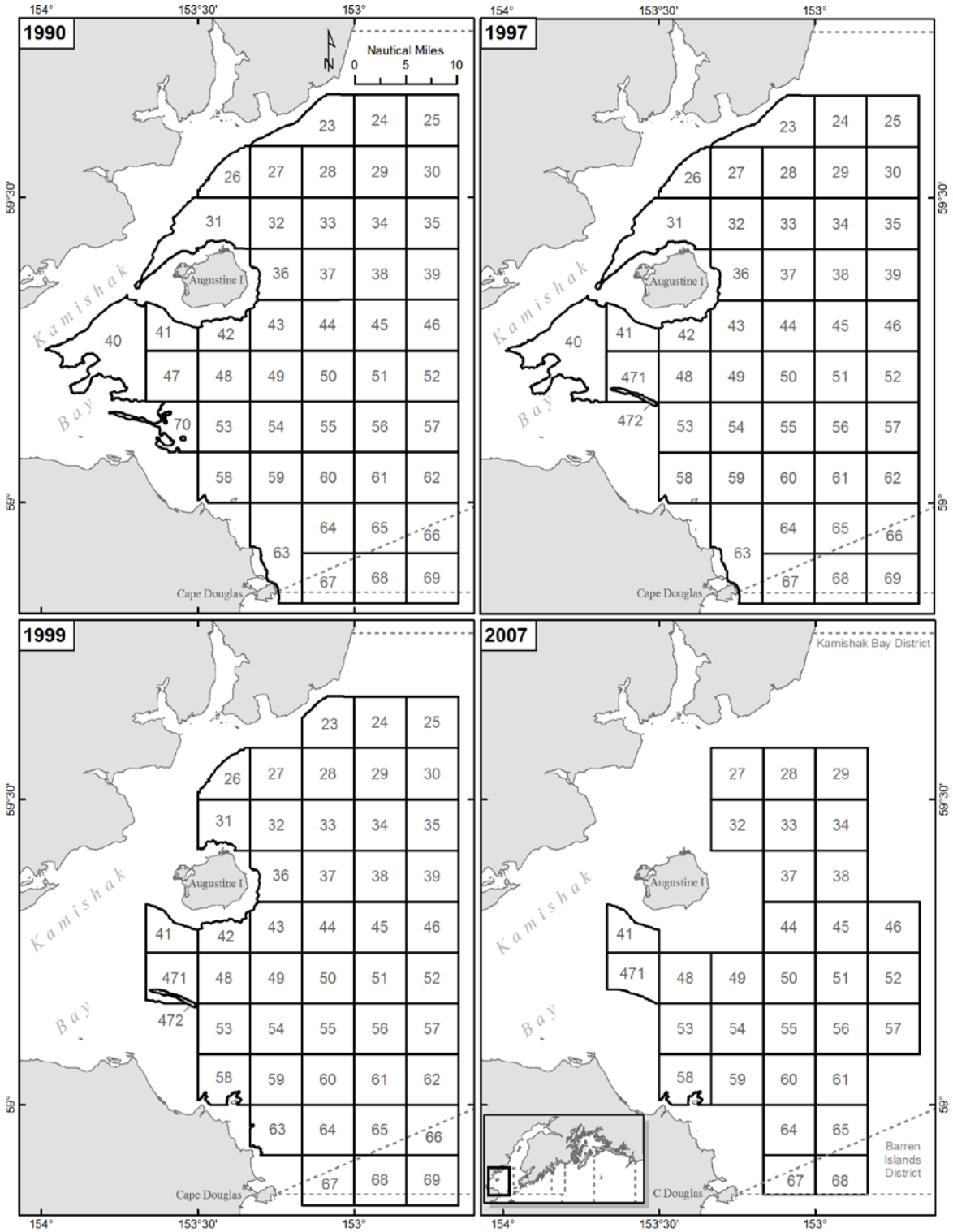


Figure 3.–Maps showing changes in the Kamishak Bay Barren Islands Districts bottom trawl survey grids.

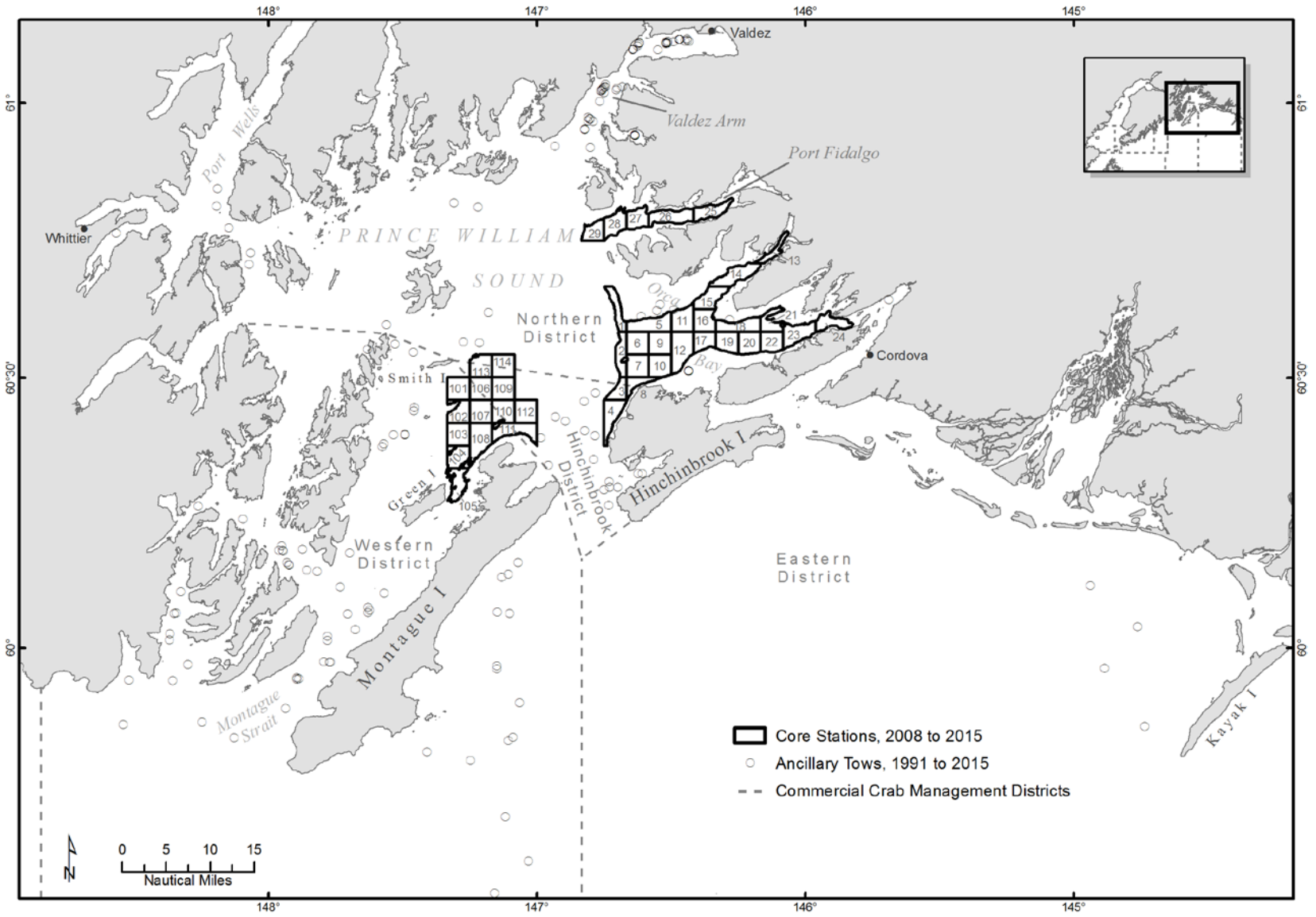


Figure 4.–Map showing the Prince William Sound bottom trawl survey grid core stations and ancillary stations by tow midpoints, 1991–2015.

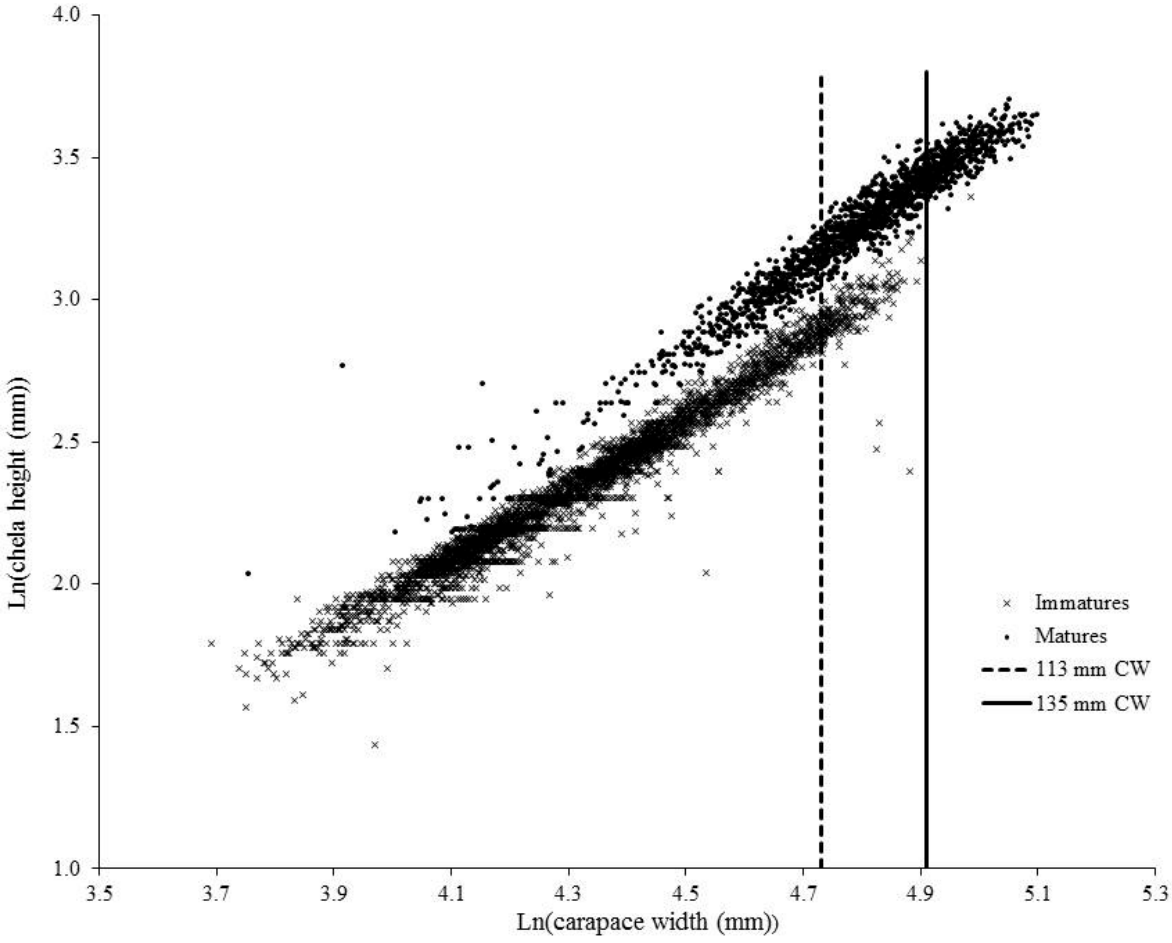


Figure 5.–Relationship between log carapace width and log chela height, and separation of immature and mature males for PWSMA Tanner crab based on the output of the program MATURE.

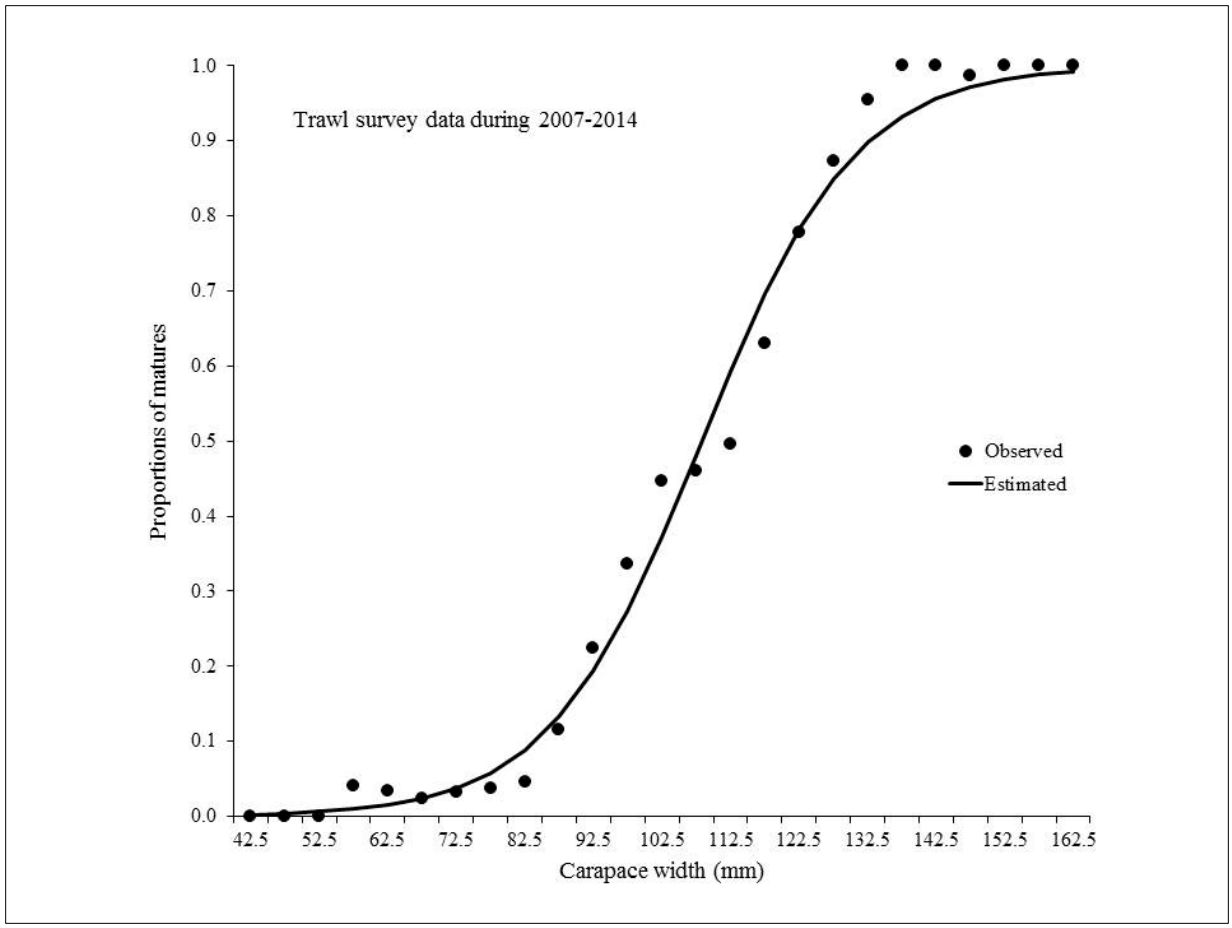


Figure 6.–Proportions of mature male Tanner crab in PWSMA based on the output from the program MATURE.

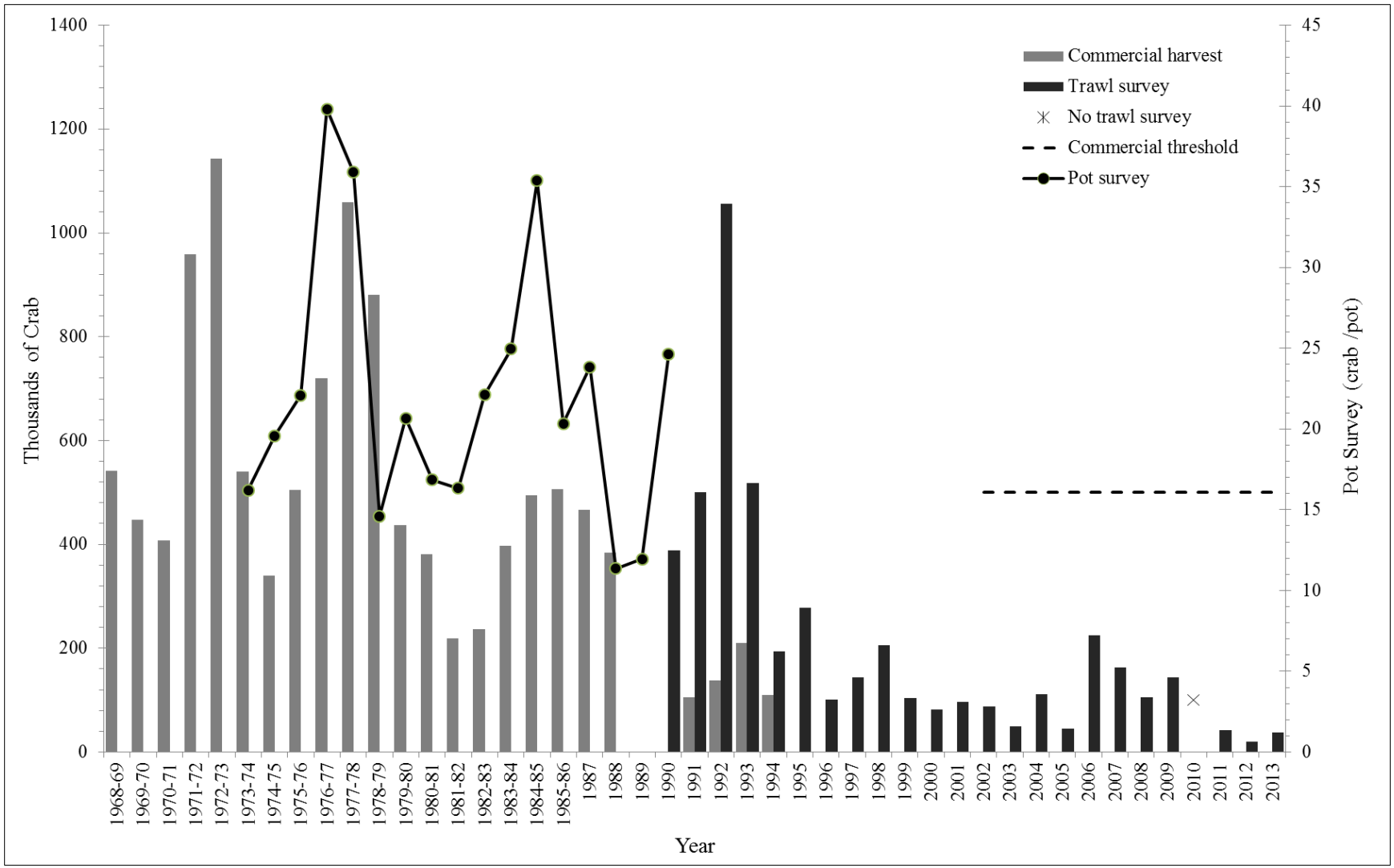


Figure 7.–Historical fishery harvests along with pot and bottom trawl survey results for legal male Tanner crab in the Southern District.

Note: The minimum stock size threshold for a commercial fishery was instituted in 2002.

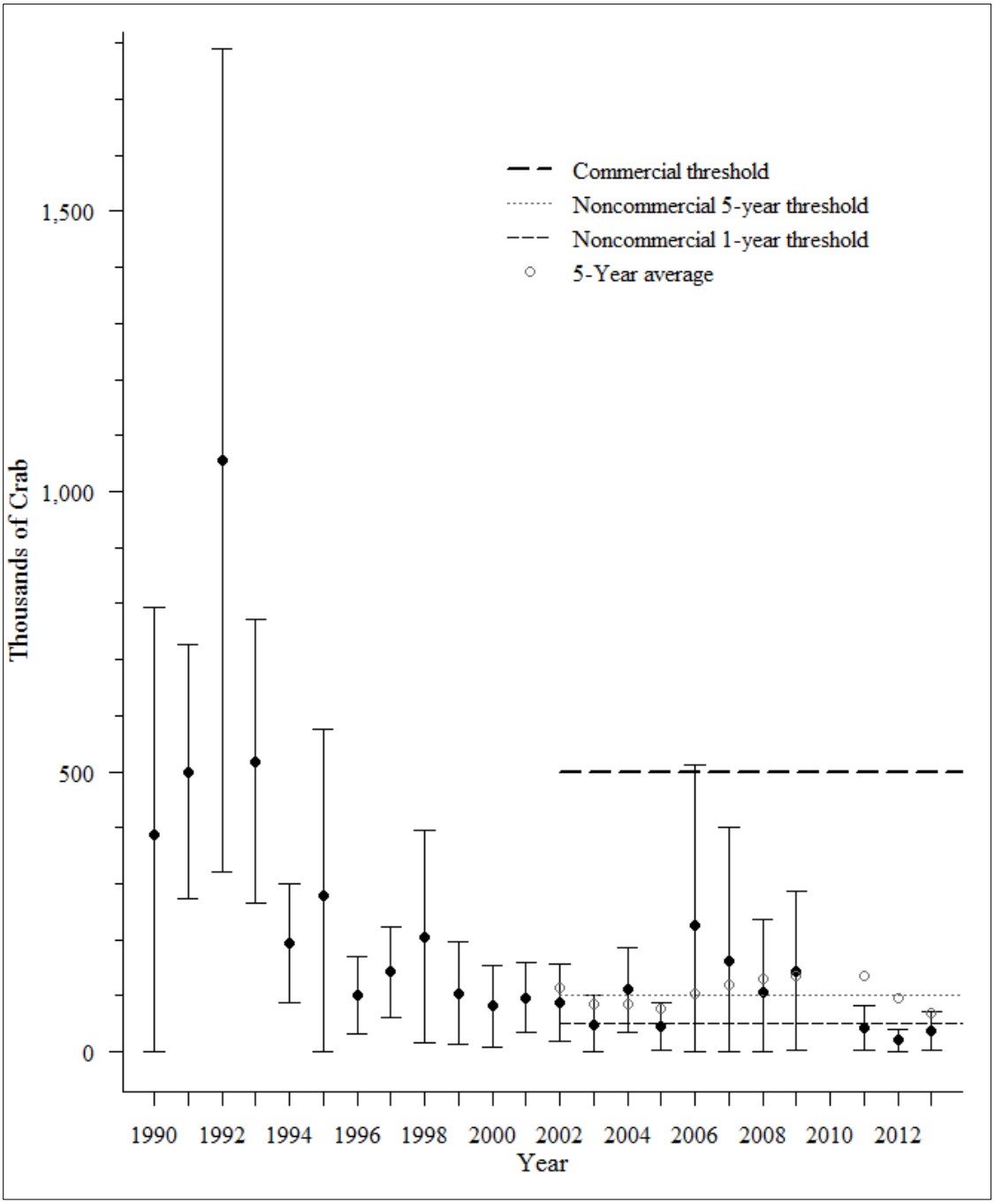


Figure 8.–Abundance estimates of legal male Tanner crab from bottom trawl surveys in the Southern District from 1990 to 2013 with 95% confidence intervals and thresholds for opening and closing commercial and noncommercial fisheries.

Note: The thresholds were instituted in 2002.

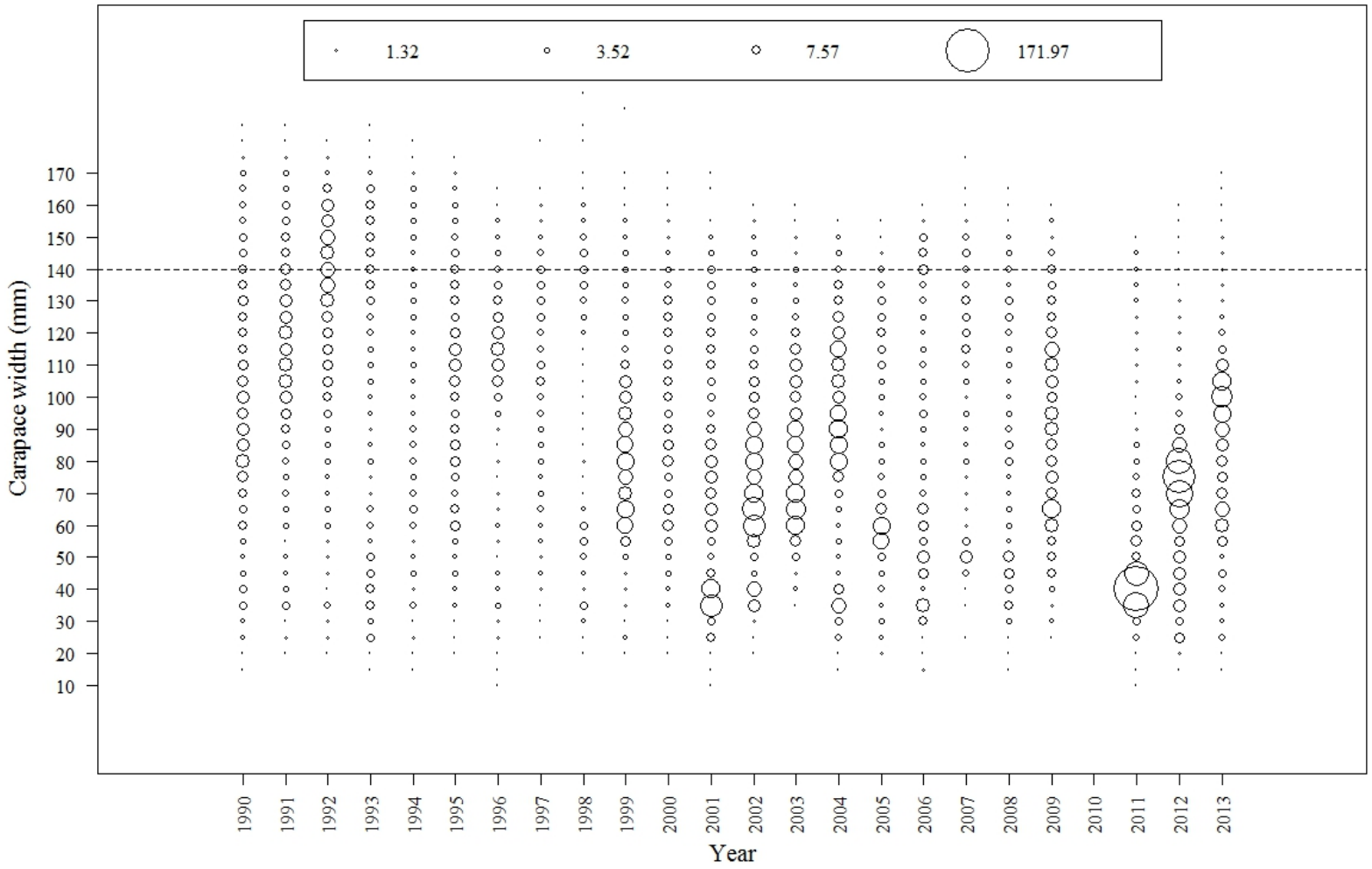


Figure 9.–Mean standardized catch of Tanner crab for 5 mm carapace width bins by year from the Kachemak Bay trawl survey in the Southern District.

Note: Circles sized with radius proportional to mean catch. Horizontal dashed line is legal size.

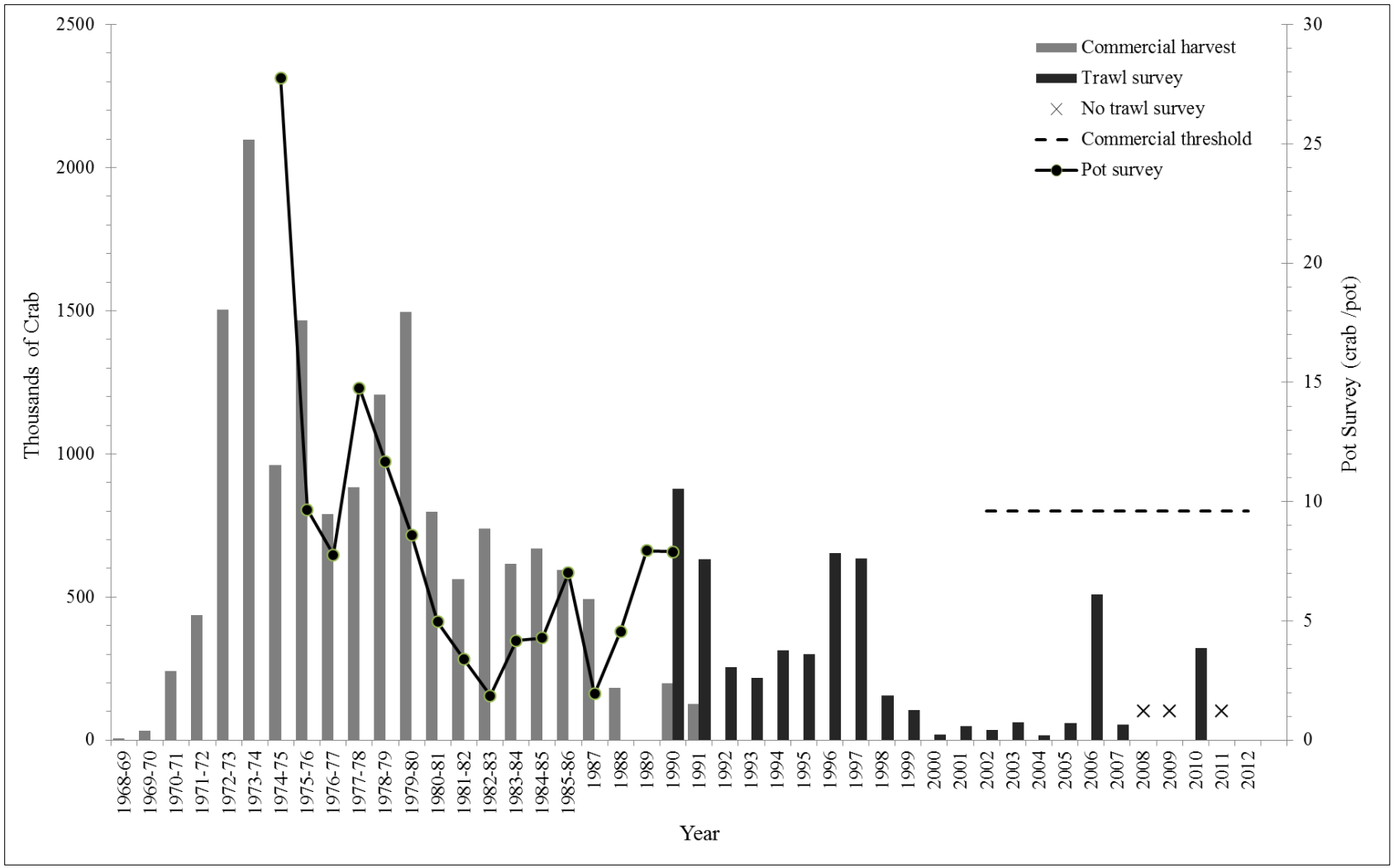


Figure 10.–Historical fishery harvests along with pot and bottom trawl survey results for legal male Tanner crab in the Kamishak and Barren Islands Districts.

Note: The minimum stock size threshold for a commercial fishery was instituted in 2002. No legal crab were caught in the 2012 survey.

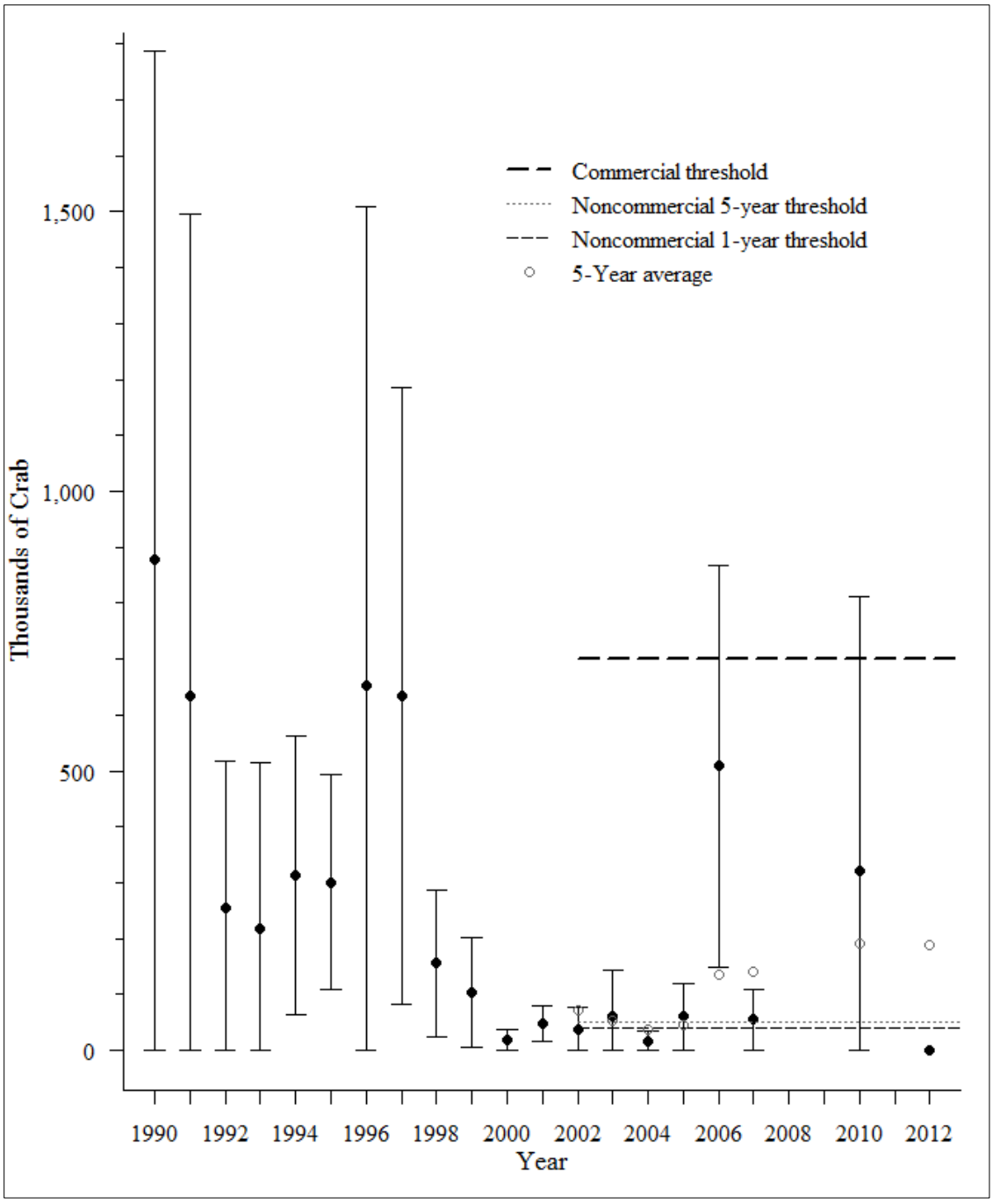


Figure 11.–Abundance estimates of legal male Tanner crab from bottom trawl surveys in the Kamishak and Barren Islands Districts from 1990 to 2012 with 95% confidence intervals and thresholds for opening and closing commercial and noncommercial fisheries.

Note: The thresholds were instituted in 2002.

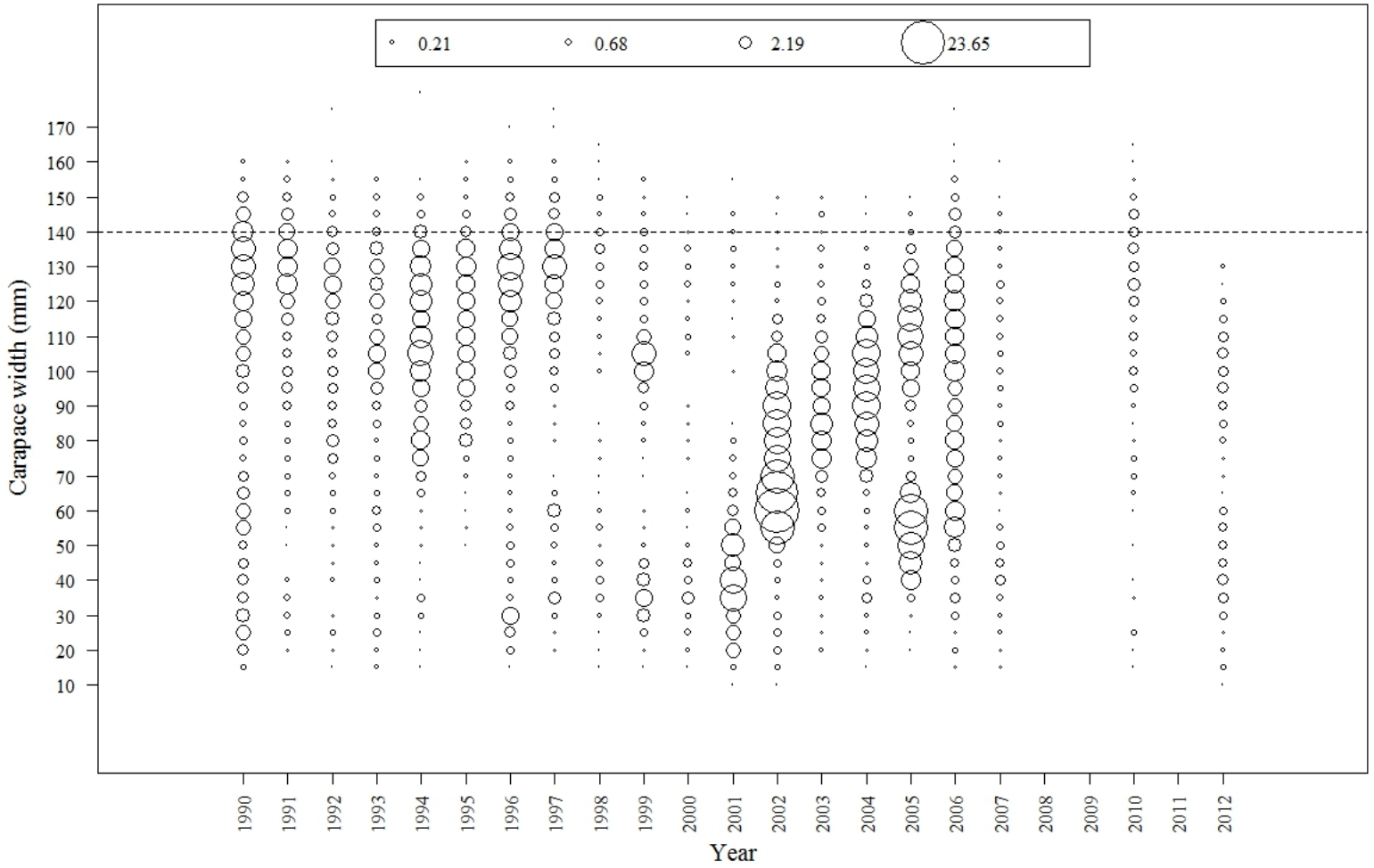


Figure 12.–Mean standardized catch of Tanner crab for 5 mm carapace width bins by year from the Kamishak Bay trawl survey in the Kamishak Bay Barren Islands Districts.

Note: Circles sized with radius proportional to mean catch. Horizontal dashed line is the legal size.

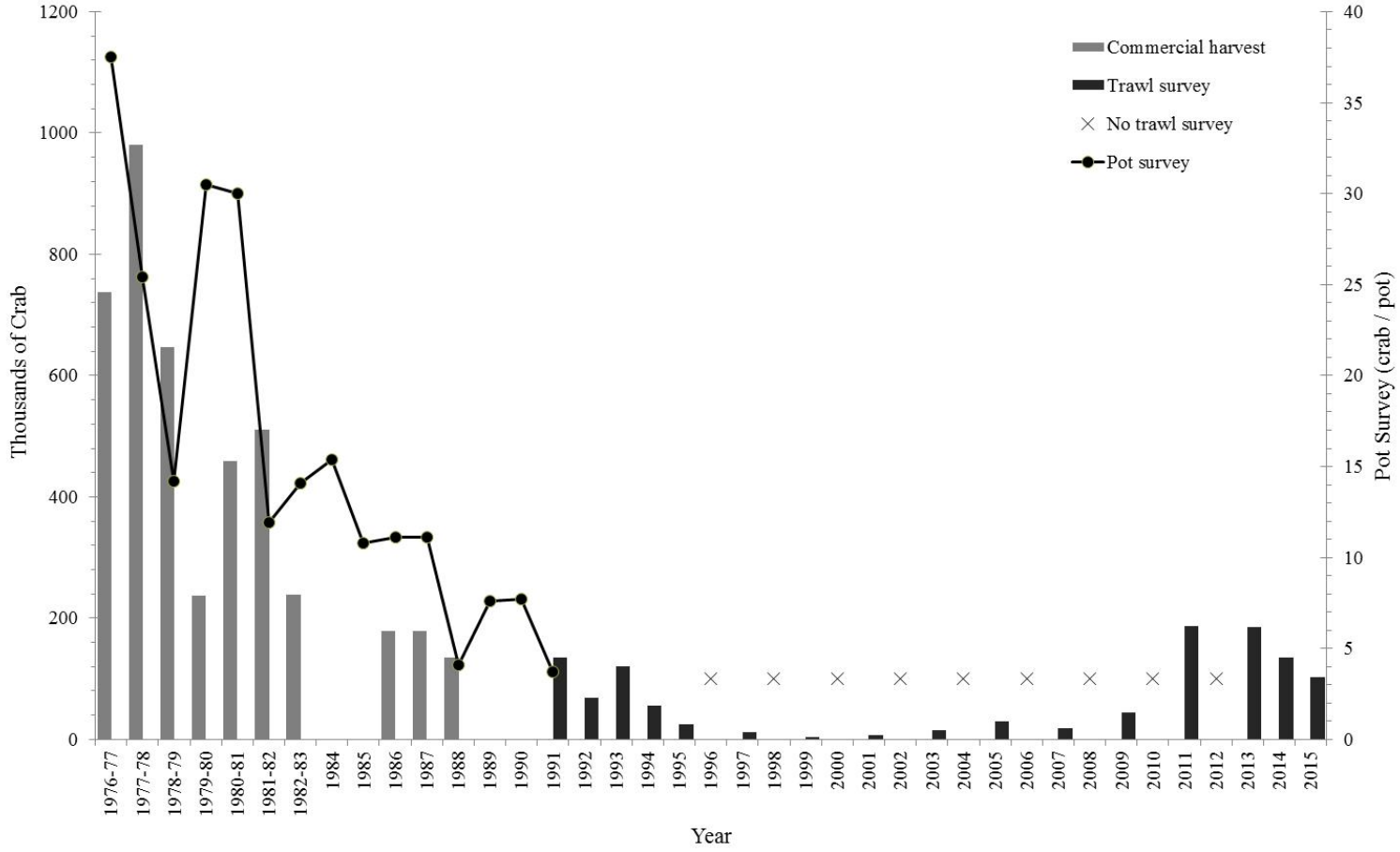


Figure 13.–Historical fishery harvests along with pot and bottom trawl survey results for legal male Tanner crab in the Prince William Sound Management Area.

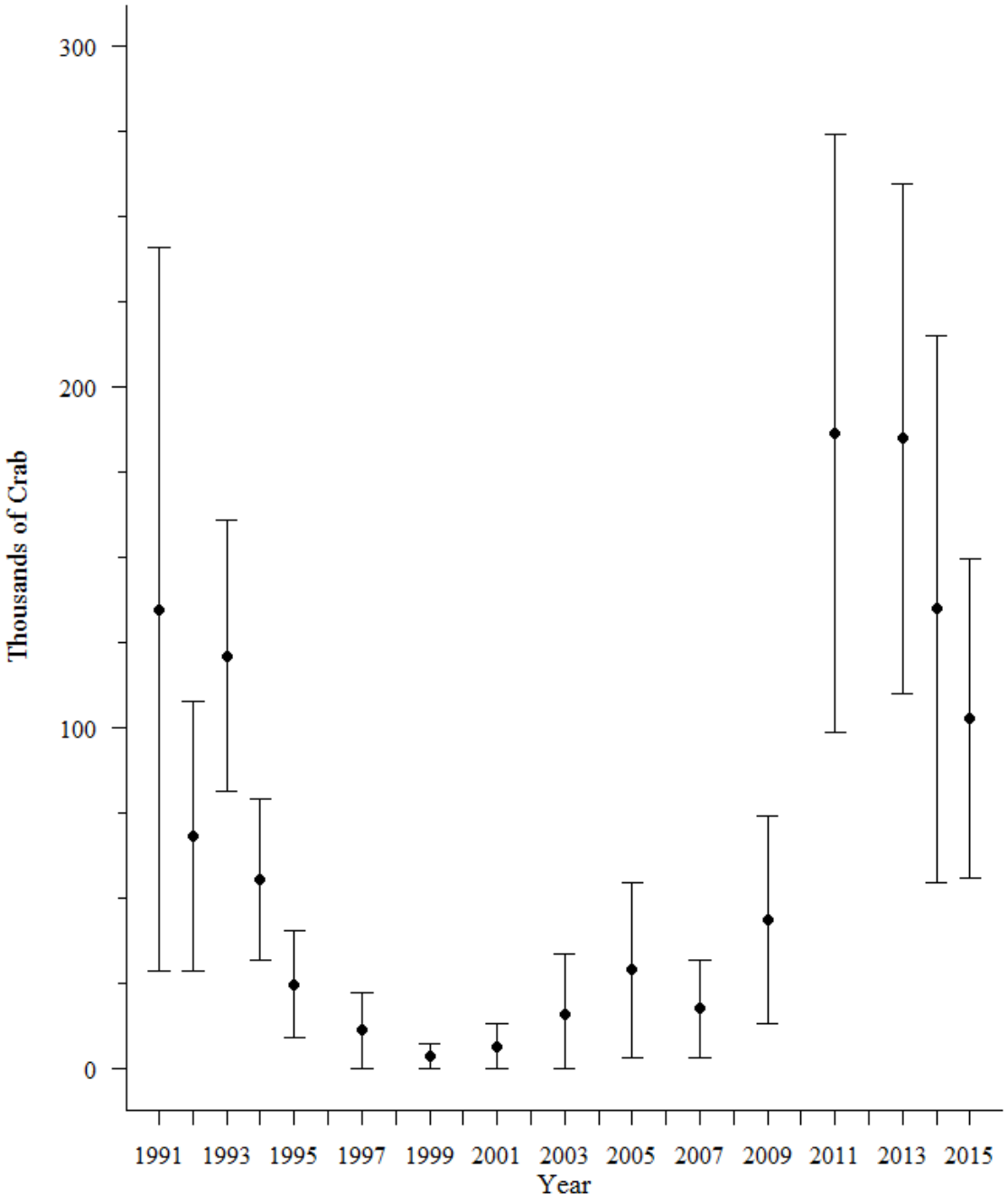


Figure 14.–Abundance estimates of legal male Tanner crab from bottom trawl surveys in the Prince William Sound Management Area from 1990 to 2015 with 95% confidence intervals.

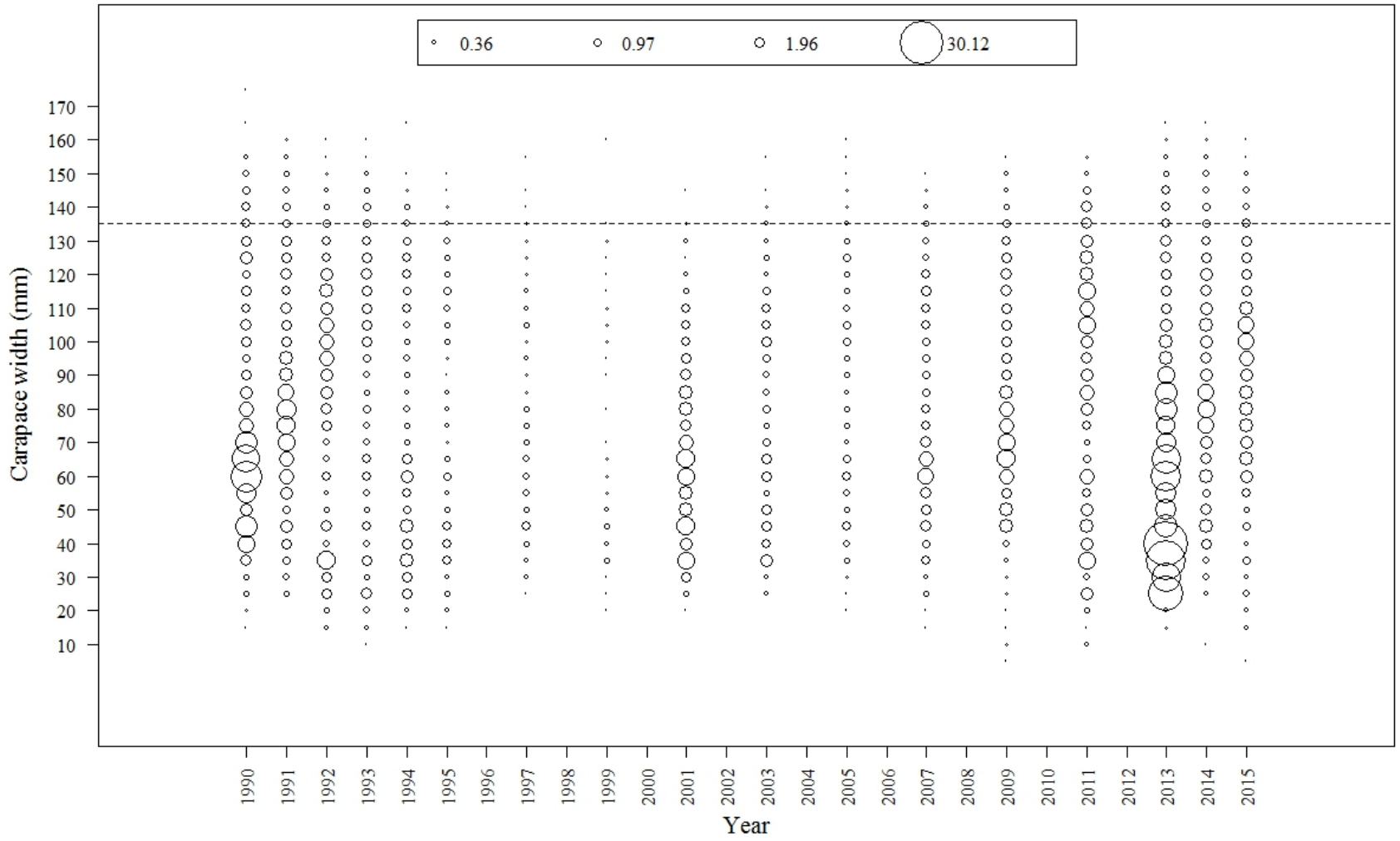


Figure 15.–Mean standardized catch of Tanner crab for 5 mm carapace width bins by year from the Prince William Sound trawl survey.

Note: Circles sized with radius proportional to mean catch. Horizontal dashed line is the legal size.

APPENDIX A: ONBOARD CATCH SAMPLING

Appendix A1.–Chronology of the Southern District bottom trawl survey, 1990–2013.

						Stations surveyed	
Year	Dates	Headrope (ft)	Tow length (nmi)	Vessel	Survey grid	Core	Total
1990	7/6–7/11	70	1	Pandalus	SD1990	14	19
1991	7/17–7/31	70	1	Pandalus	SD1990	15	20
1992	7/14–7/24	70	1	Pandalus	SD1992	15	18
1993	7/6–7/14	70	1	Pandalus	SD1992	16	20
1994	6/27–7/6	70	1	Pandalus	SD1992	16	20
1995	7/5–7/10	70	1	Pandalus	SD1992	16	20
1996	8/17–8/20	70	1	Pandalus	SD1992	16	19
1997	6/26–7/1	70	1	Pandalus	SD1992	16	23
1998	8/13–8/19	70	1	Pandalus	SD1992	16	23
1999	7/19–7/23	70	1	Pandalus	SD1992	16	20
2000	7/10–7/17	70 / 78	1	Pandalus	SD1992	16	23
2001	5/29–6/4	70 / 78	1	Pandalus	SD1992	16	22
2002	7/8–7/17	78	1	Pandalus	SD1992	14	21
2003	7/1–7/9	78	1	Pandalus	SD1992	16	23
2004	6/16–6/20	78	1	Pandalus	SD1992	16	23
2005	6/27–7/1	78	1	Pandalus	SD1992	15	22
2006	9/25–10/4	78	1	Pandalus	SD1992	17	23
2007	9/10–9/17	78	1	Pandalus	SD1992	16	23
2008	9/23–9/29	78	1	Pandalus	SD2008	16	16
2009	5/18–5/22	78	1	Pandalus	SD2008	15	16
2010	NS						
2011	6/23–6/29	78	0.5	Solstice	SD2011	37	37
2012	6/15–6/21	78	0.5	Solstice	SD2011	37	37
2013	6/15–6/21	78	0.5	Solstice	SD2011	37	38

Note: NS is no survey.

Appendix A2.–Chronology of the Kamishak Bay and Barren Islands Districts bottom trawl survey, 1990–2012.

						Stations surveyed	
Year	Dates	Headrope (ft)	Tow length (nmi)	Vessel	Survey grid	Core	Total
1990	7/12–7/17	70	1	Pandalus	KBBI1990	24	26
1991	7/18–7/22	70	1	Pandalus	KBBI1990	17	20
1992	6/20–7/21	70	1	Pandalus	KBBI1990	25	32
1993	6/27–7/3	70	1	Pandalus	KBBI1990	15	16
1994	6/13–6/20	70	1	Pandalus	KBBI1990	17	17
1995	6/18–6/24	70	1	Pandalus	KBBI1990	24	27
1996	6/20–6/23	70	1	Pandalus	KBBI1990	18	19
1997	6/8–6/12	70	1	Pandalus	KBBI1997	18	19
1998	6/16–6/30	70	1	Pandalus	KBBI1997	22	23
1999	8/16–8/23	70	1	Pandalus	KBBI1999	19	20
2000	6/22–6/25	70 / 78	1	Pandalus	KBBI1999	24	27
2001	6/10–6/16	70 / 78	1	Pandalus	KBBI1999	24	25
2002	6/28–7/2	78	1	Pandalus	KBBI1999	19	24
2003	6/18–6/22	78	1	Pandalus	KBBI1999	17	18
2004	6/22–6/26	78	1	Pandalus	KBBI1999	22	23
2005	6/15–6/19	78	1	Pandalus	KBBI1999	21	21
2006	5/23–5/28	78	1	Pandalus	KBBI1999	27	27
2007	7/11–7/16	78	1	Pandalus	KBBI2007	24	24
2008	NS						
2009	NS						
2010	8/1–8/5	78	1	Pandalus	KBBI2007	23	24
2011	NS						
2012	6/9–6/13	78	1	Solstice	KBBI2007	23	23

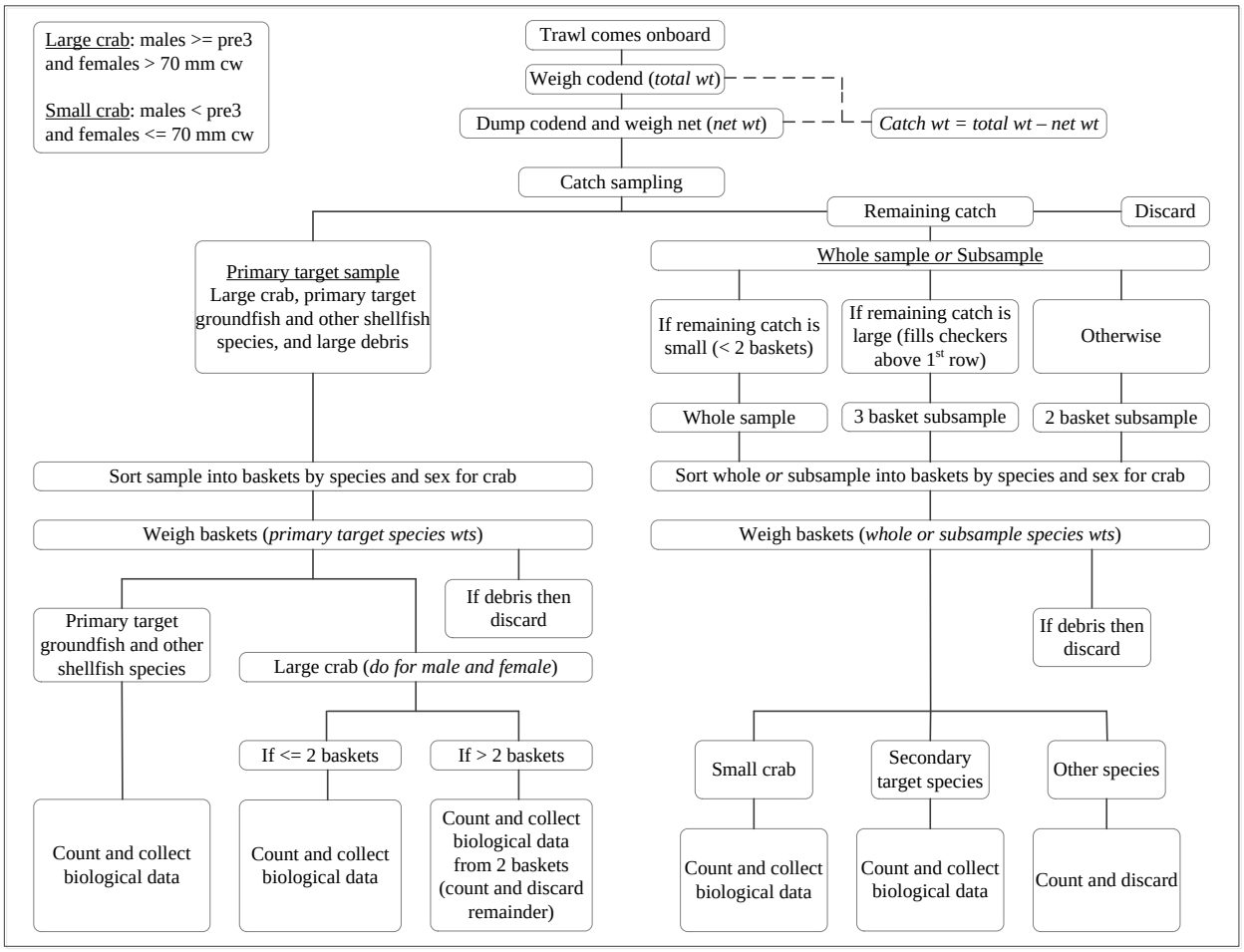
Note: NS is no survey.

Appendix A3.–Chronology of the Prince William Sound Management Area bottom trawl survey, 1991–2015.

						Stations surveyed	
Year	Dates	Headrope (ft)	Tow length (nmi)	Vessel	Survey grid	Core	Total
1991	8/20–8/30	70	1	Pandalus	PWSMA1991	29	43
1992	8/3–8/13	70	1	Pandalus	PWSMA1991	37	42
1993	7/22–8/2	70	1	Pandalus	PWSMA1991	38	48
1994	7/19–7/25	70	1	Pandalus	PWSMA1991	38	44
1995	7/29–8/3	70	1	Pandalus	PWSMA1991	32	33
1996	NS						
1997	8/16–8/26	70	1	Pandalus	PWSMA1991	39	53
1998	NS						
1999	6/28–7/12	70	1	Pandalus	PWSMA1991	40	66
2000	NS						
2001	7/17–7/28	70 / 78	1	Pandalus	PWSMA1991	40	52
2002	NS						
2003	8/10–8/20	78	1	Pandalus	PWSMA1991	40	44
2004	NS						
2005	7/11–7/24	78	1	Pandalus	PWSMA1991	40	57
2006	NS						
2007	7/22–8/1	78	1	Pandalus	PWSMA1991	32	43
2008	NS						
2009	7/9–7/19	78	1	Pandalus	PWSMA2008	43	50
2010	NS						
2011	6/6–7/14	78	1	Solstice	PWSMA2008	43	51
2012	NS						
2013	7/5–7/14	78	1	Solstice	PWSMA2008	43	48
2014	6/3–6/12	78	1	Solstice	PWSMA2008	41	46
2015	6/20–6/29	78	1	Solstice	PWSMA2008	43	48

Note: NS is no survey.

Appendix A4.–Details of onboard catch sampling process for Central Region large-mesh trawl surveys.



APPENDIX B: STANDARDIZED CATCH PER UNIT EFFORT FOR MALE AND FEMALE TANNER CRAB FROM BOTTOM TRAWL SURVEYS

Appendix B1.–Standardized catch per unit effort (CPUE; crab per nautical mile) of male Tanner crab from bottom trawl surveys in the Southern District, 1990–2013.

		No. sublegal males by pre-recruit Size (CW)				Legal males			
Year	Tows	<70 mm	70–91 mm	92–114 mm	115–139 mm	>140 mm	Legal SD	Total	Total SD
1990	14	40.3	58.6	49.8	39.9	31.5	56.7	220.0	160.9
1991	15	23.8	22.5	65.1	68.7	40.5	33.2	220.6	128.8
1992	15	19.2	10.1	36.9	73.1	85.6	107.5	224.9	160.7
1993	16	46.9	7.3	11.0	26.4	42.0	38.7	133.5	65.5
1994	16	25.3	17.0	10.8	12.9	15.7	16.2	81.6	68.7
1995	16	28.9	31.6	45.8	41.0	22.6	45.1	169.9	197.8
1996	16	15.1	3.6	42.4	48.7	8.2	10.6	118.0	178.7
1997	16	13.9	10.0	23.3	26.4	11.6	12.3	85.2	49.3
1998	16	26.4	1.6	1.9	15.8	16.7	28.9	62.5	56.9
1999	16	73.9	94.0	56.5	16.3	8.5	14.0	249.2	417.6
2000	16	41.6	36.8	31.7	30.8	6.7	11.1	147.6	114.8
2001	16	131.3	53.1	25.9	31.8	7.9	9.3	250.0	303.7
2002	14	164.3	103.4	40.5	17.1	7.1	9.8	332.4	294.8
2003	16	99.6	96.3	57.6	23.4	3.9	8.1	280.8	262.8
2004	16	54.4	90.7	84.1	55.4	9.0	11.5	293.6	285.5
2005	15	84.6	15.1	15.2	28.1	3.7	6.1	146.7	158.6
2006	17	83.4	12.5	18.6	18.3	18.2	45.3	151.2	288.5
2007	16	27.5	7.5	14.3	30.2	13.2	36.4	92.7	190.6
2008	16	44.8	18.2	12.9	19.4	8.5	19.9	103.9	119.8
2009	15	81.1	52.1	69.1	45.0	11.7	20.8	258.9	342.4
2010		NS							
2011	37	333.1	12.9	3.3	7.7	3.5	9.9	360.4	482.5
2012	37	164.6	205.2	15.3	4.6	1.7	4.9	391.4	437.0
2013	37	75.0	55.2	112.7	11.4	3.1	8.3	257.6	237.2

Note: NS is no survey; SD is standard deviation.

Appendix B2.–Standardized catch per unit effort (CPUE; crab per nautical mile) of female Tanner crab from bottom trawl surveys in the Southern District, 1990–2013.

Year	Tows	Juvenile	SD	Mature	SD	Total	SD
1990	14	79.9	61.2	35.5	66.2	115.4	83.9
1991	15	39.4	51.4	68.8	121.1	108.2	160.0
1992	15	23.3	27.7	60.7	133.1	84.0	133.9
1993	16	46.0	49.2	46.8	92.9	92.9	90.5
1994	16	52.1	79.8	31.2	50.1	83.3	106.2
1995	16	54.7	64.6	70.0	122.7	124.7	144.0
1996	16	18.1	22.2	41.0	81.2	59.1	89.7
1997	16	15.3	13.9	24.8	48.2	40.1	52.6
1998	16	32.4	46.2	6.4	23.6	38.7	48.8
1999	16	100.3	165.5	45.9	90.6	146.2	209.7
2000	16	56.1	83.6	20.3	45.9	76.4	90.2
2001	16	175.2	353.3	36.2	66.6	211.4	358.1
2002	14	222.9	214.1	35.3	57.7	258.2	241.4
2003	16	106.6	148.6	19.8	20.5	126.4	164.6
2004	16	100.8	94.1	153.1	329.4	253.9	384.5
2005	15	79.9	121.4	18.2	52.2	98.1	123.1
2006	17	76.0	208.1	2.4	5.7	78.3	209.1
2007	16	48.9	92.0	122.3	484.6	171.3	573.3
2008	16	46.6	51.9	18.7	47.3	65.3	61.5
2009	15	114.8	170.1	124.0	171.0	238.8	293.9
2010	NS						
2011	37	331.4	543.9	20.1	43.2	351.6	542.8
2012	37	375.9	532.3	53.7	109.9	429.5	614.7
2013	37	95.3	113.3	158.7	329.3	253.9	374.9

Note: NS is no survey; SD is standard deviation.

Appendix B3.–Standardized catch per unit effort (CPUE; crab per nautical mile) of male Tanner crab from bottom trawl surveys in the Kamishak and Barren Islands Districts, 1990–2012.

		Number of sublegal males by pre-recruit size (CW)				Legal males			
Year	Tows	<70 mm	70–91 mm	92–114 mm	115–139 mm	>140 mm	Legal SD	Total	Total SD
1990	24	20.0	3.5	10.6	30.0	7.5	18.4	71.7	108.0
1991	17	3.1	2.2	5.5	20.7	5.4	14.3	36.9	61.1
1992	25	2.5	5.5	5.9	13.9	2.2	5.4	30.0	54.3
1993	15	5.3	2.5	12.5	11.1	1.9	4.6	33.2	42.9
1994	17	2.9	12.7	23.8	23.4	2.7	4.1	65.6	112.5
1995	24	0.4	5.4	17.2	19.2	2.6	3.9	44.7	66.3
1996	18	9.3	2.2	8.8	31.6	5.6	14.7	57.5	74.8
1997	18	7.3	0.3	5.1	22.1	5.4	9.4	40.3	45.5
1998	22	3.8	0.4	0.8	4.0	1.3	2.5	10.2	14.6
1999	19	10.7	1.3	16.1	4.4	0.9	1.7	33.5	92.1
2000	24	5.8	0.6	0.6	1.8	0.2	0.4	9.0	12.2
2001	24	41.7	1.4	0.3	1.2	0.4	0.7	45.0	115.4
2002	19	71.2	42.1	18.8	1.8	0.3	0.7	134.2	307.1
2003	17	4.4	17.8	13.1	2.9	0.5	1.4	38.7	66.6
2004	22	4.8	25.1	34.5	5.4	0.1	0.4	69.8	82.7
2005	21	53.4	3.2	26.6	17.9	0.5	1.1	101.6	211.8
2006	27	21.2	15.5	19.0	20.4	4.3	7.7	80.4	93.7
2007	24	5.2	1.3	2.1	2.4	0.5	1.1	11.4	14.2
2008	NS								
2009	NS								
2010	23	1.2	1.0	3.6	6.9	2.7	9.6	15.5	51.8
2011	NS								
2012	23	8.3	2.3	6.4	0.8	0.0	0.0	17.8	39.9

Note: NS is no survey; SD is standard deviation.

Appendix B4.–Standardized catch per unit effort (CPUE; crab per nautical mile) of female Tanner crab from bottom trawl surveys in the Kamishak and Barren Islands Districts, 1990–2012.

Year	Tows	Juvenile	SD	Mature	SD	Total	SD
1990	24	23.4	49.0	5.6	14.7	29.0	59.9
1991	17	4.1	5.0	1.2	2.9	5.3	7.0
1992	25	4.5	9.0	2.2	6.7	6.7	14.8
1993	15	6.9	12.9	14.1	35.3	21.0	38.4
1994	17	7.3	11.2	14.1	27.8	21.4	36.6
1995	24	2.3	4.3	5.5	12.7	7.8	14.4
1996	18	8.7	20.9	2.0	5.4	10.7	21.1
1997	18	3.1	6.5	1.1	1.7	4.2	6.6
1998	22	3.3	5.9	0.1	0.3	3.4	5.9
1999	19	10.8	36.3	0.6	1.7	11.3	36.2
2000	24	5.8	9.7	0.0	0.2	5.9	9.7
2001	24	40.6	103.6	0.9	3.0	41.5	105.8
2002	19	74.4	167.8	10.9	33.6	85.3	193.8
2003	17	10.1	27.5	20.0	43.7	30.1	69.5
2004	22	4.6	9.1	18.7	53.1	23.3	60.6
2005	21	56.3	199.0	2.5	5.4	58.9	200.7
2006	27	31.9	53.7	10.1	19.6	42.2	60.4
2007	24	4.5	8.1	0.4	1.0	4.9	8.2
2008		NS					
2009		NS					
2010	23	1.6	2.7	0.2	0.7	1.7	3.1
2011		NS					
2012	23	7.6	10.4	2.0	7.3	9.5	13.9

Note: NS is no survey; SD is standard deviation.

Appendix B5.–Standardized catch per unit effort (CPUE; crab per nautical mile) of male Tanner crab from bottom trawl surveys in the Prince William Sound Management Area, 1990–2015.

		Number of sublegal males by pre-recruit size (CW)				Legal males			
Year	Tows	<73 mm	73–92 mm	93–112 mm	113–134 mm	>135 mm	Legal SD	Total	Total SD
1991	29	22.0	18.4	8.6	7.3	3.6	7.4	59.8	98.5
1992	37	15.9	8.4	12.9	8.4	1.8	3.1	47.4	48.0
1993	38	12.4	3.1	6.0	7.0	3.2	3.2	31.8	34.8
1994	38	17.7	2.1	3.3	4.8	1.5	1.9	29.3	38.9
1995	32	7.8	1.1	1.9	2.7	0.7	1.1	14.1	12.6
1996	NS								
1997	39	5.5	1.5	1.3	0.9	0.3	0.9	9.6	12.9
1998	NS								
1999	40	3.1	0.2	0.7	0.4	0.1	0.3	4.6	5.3
2000	NS								
2001	40	36.0	10.7	5.9	1.6	0.2	0.5	54.3	64.7
2002	NS								
2003	40	13.1	3.0	5.2	2.5	0.4	1.5	24.1	29.7
2004	NS								
2005	40	7.4	2.1	3.8	3.1	0.8	2.1	17.1	24.1
2006	NS								
2007	32	19.7	5.3	5.8	6.0	0.5	1.0	37.3	31.0
2008	NS								
2009	43	26.6	13.4	6.8	8.9	1.2	2.6	56.9	75.8
2010	NS								
2011	43	26.0	10.6	14.2	15.2	4.9	7.5	70.9	148.6
2012	NS								
2013	43	157.9	27.0	11.3	8.5	4.9	6.4	209.6	200.0
2014	41	21.6	16.7	11.1	8.7	3.6	6.7	61.7	54.1
2015	43	16.1	12.3	16.1	8.0	2.7	4.0	55.2	75.6

Note: NS is no survey; SD is standard deviation.

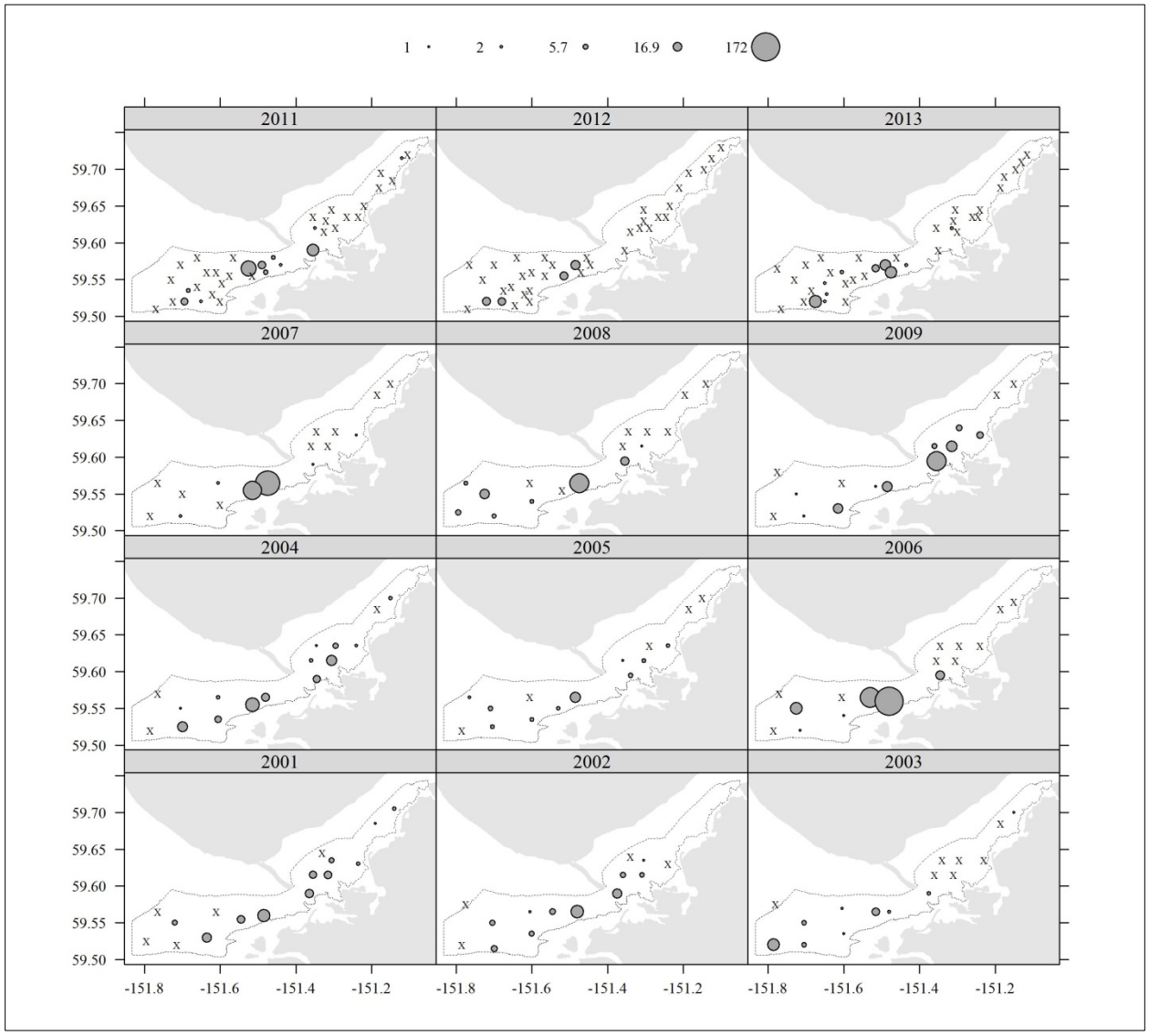
Appendix B6.–Standardized catch per unit effort (CPUE; crab per nautical mile) of female Tanner crab from bottom trawl surveys in the Prince William Sound Management Area, 1990–2015.

Year	Tows	Juvenile	SD	Mature	SD	Total	SD
1991	29	39.3	74.1	17.1	17.6	56.4	83.2
1992	37	17.6	15.4	22.7	30.8	40.3	36.1
1993	38	12.1	17.9	8.0	10.5	20.2	20.6
1994	38	18.5	38.7	5.9	8.6	24.4	40.6
1995	32	6.8	8.7	2.6	3.2	9.4	9.5
1996		NS					
1997	39	5.9	8.9	2.6	5.7	8.5	13.0
1998		NS					
1999	40	2.8	3.9	0.6	1.1	3.4	4.1
2000		NS					
2001	40	43.1	45.8	16.6	27.1	59.8	63.5
2002		NS					
2003	40	11.2	18.5	13.6	27.4	24.8	32.4
2004		NS					
2005	40	9.2	17.6	6.8	11.7	16.0	23.5
2006		NS					
2007	32	20.1	23.5	18.8	27.8	38.8	37.9
2008		NS					
2009	43	20.3	38.5	27.7	53.4	48.0	61.3
2010		NS					
2011	43	27.3	62.7	17.3	33.5	44.6	71.6
2012		NS					
2013	43	161.0	180.3	28.9	51.9	189.8	189.8
2014	41	26.7	31.2	21.4	31.8	48.1	41.8
2015	43	10.6	17.9	18.2	25.6	28.8	31.9

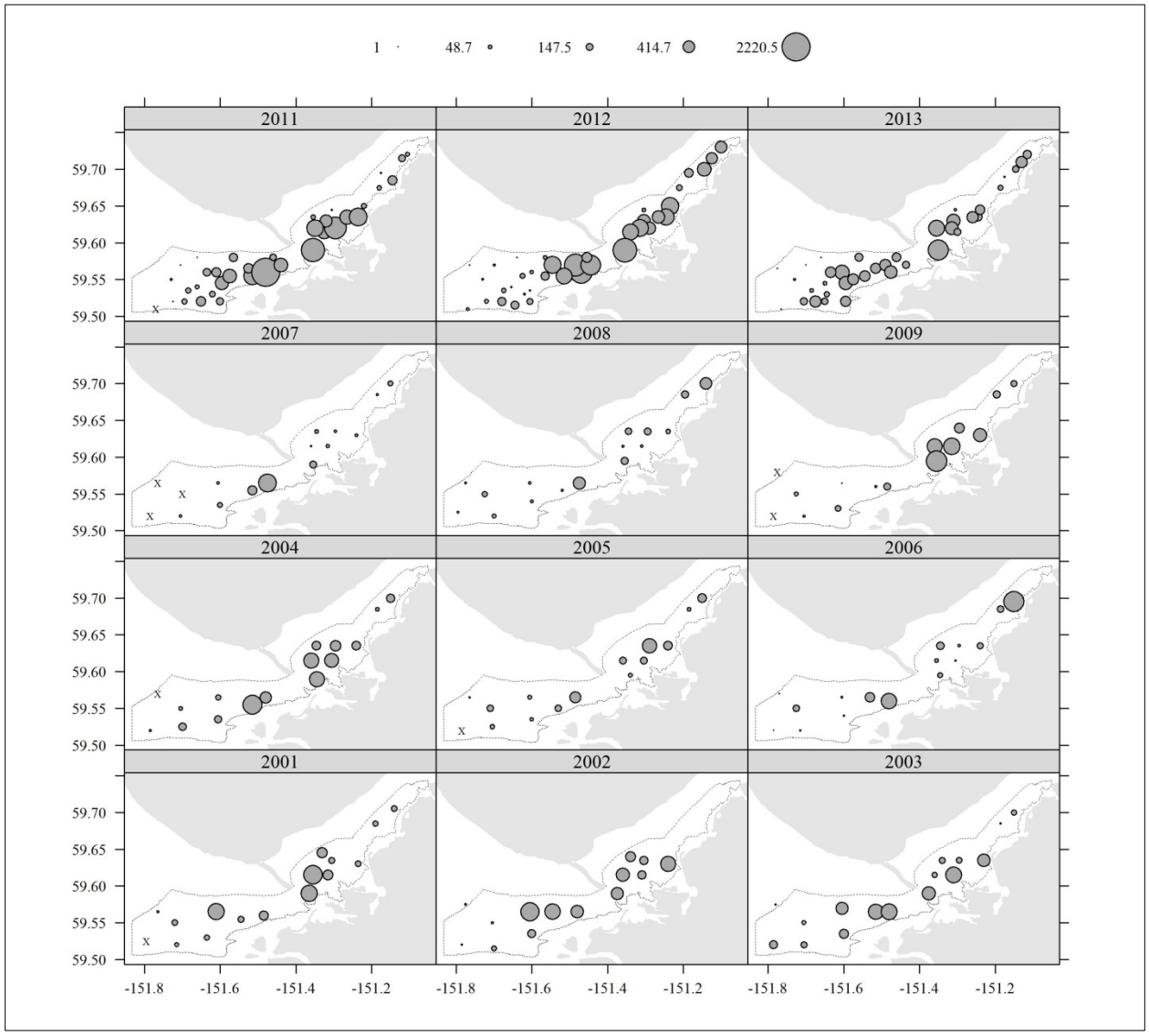
Note: NS is no survey; SD is standard deviation.

APPENDIX C: GEOGRAPHIC DISTRIBUTION MAPS FOR MALE AND FEMALE TANNER CRAB

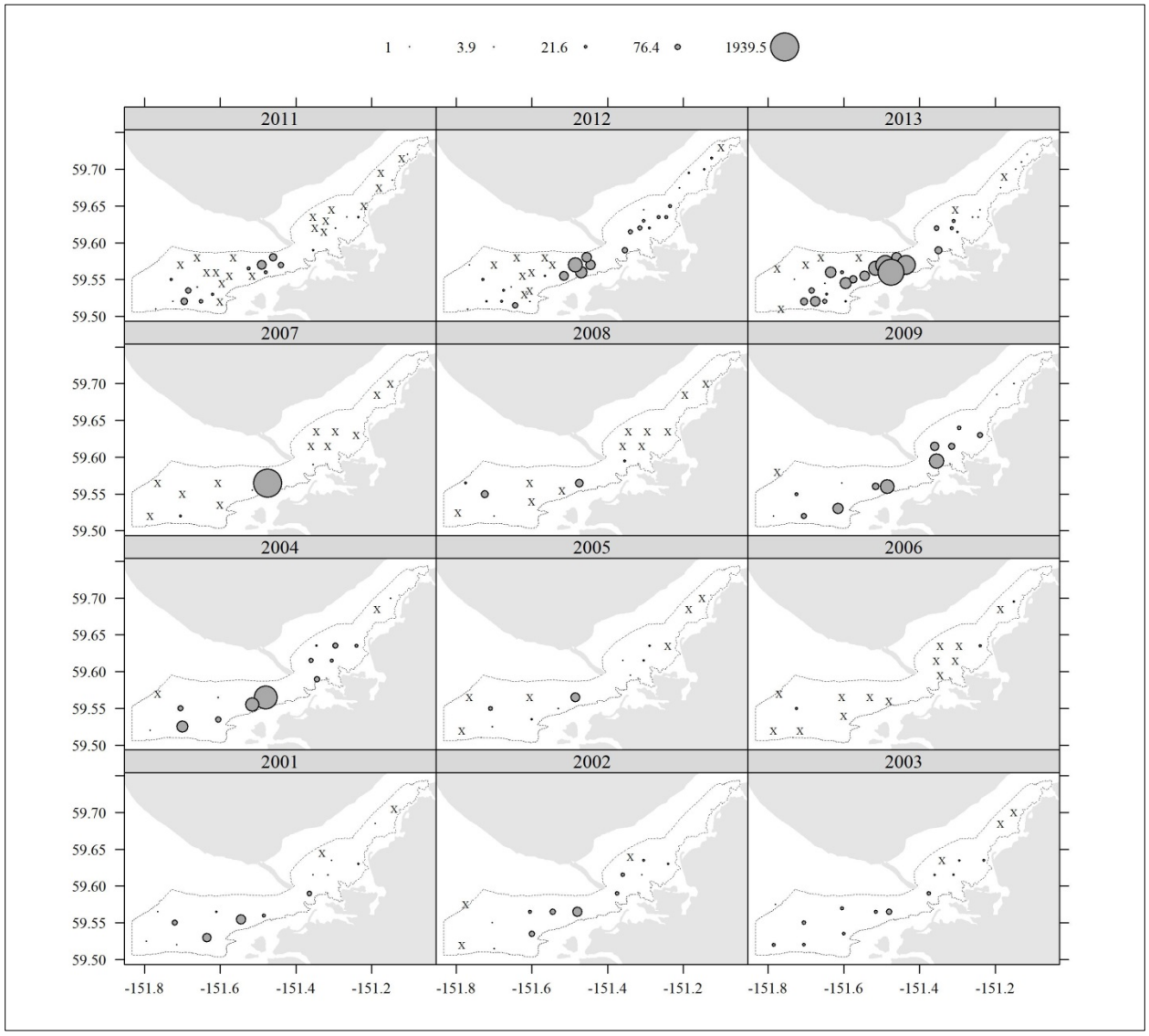
Appendix C1.–Geographic distribution of standardized catch of legal male Tanner crab in the Southern District, 2001–2013.



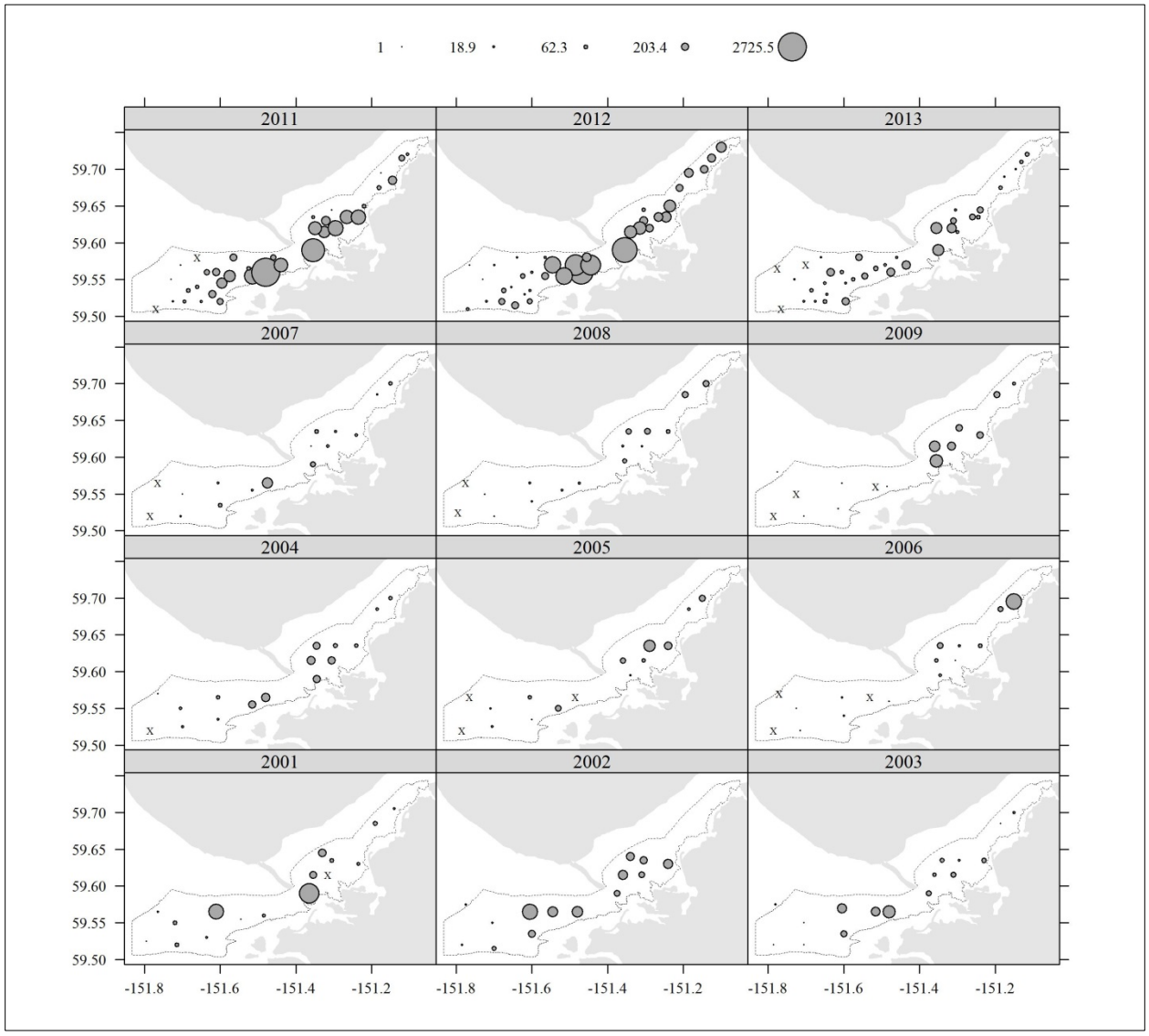
Appendix C2.–Geographic distribution of standardized catch of sublegal male Tanner crab in the Southern District, 2001–2013.



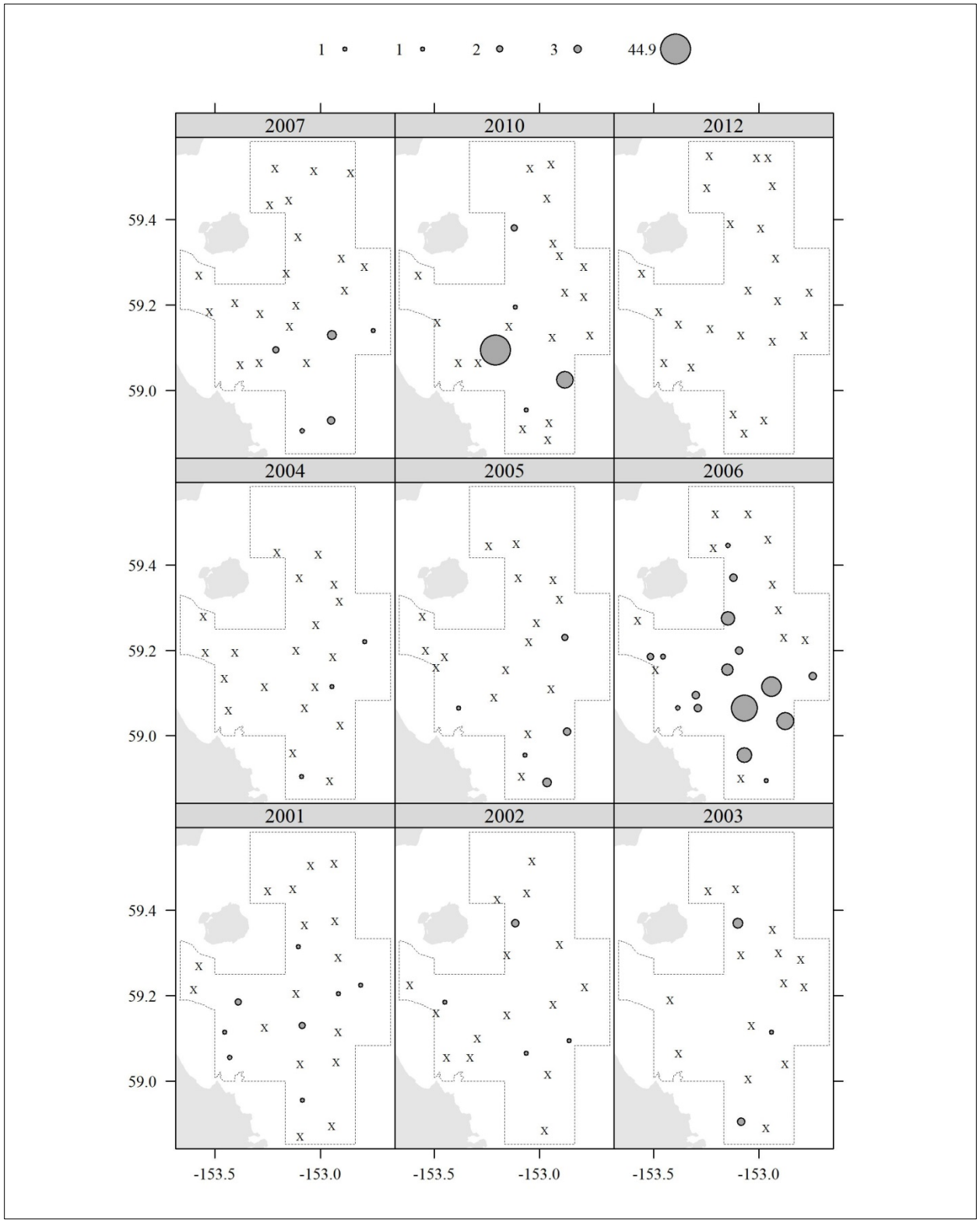
Appendix C3.–Geographic distribution of standardized catch of mature female Tanner crab in the Southern District, 2001–2013.



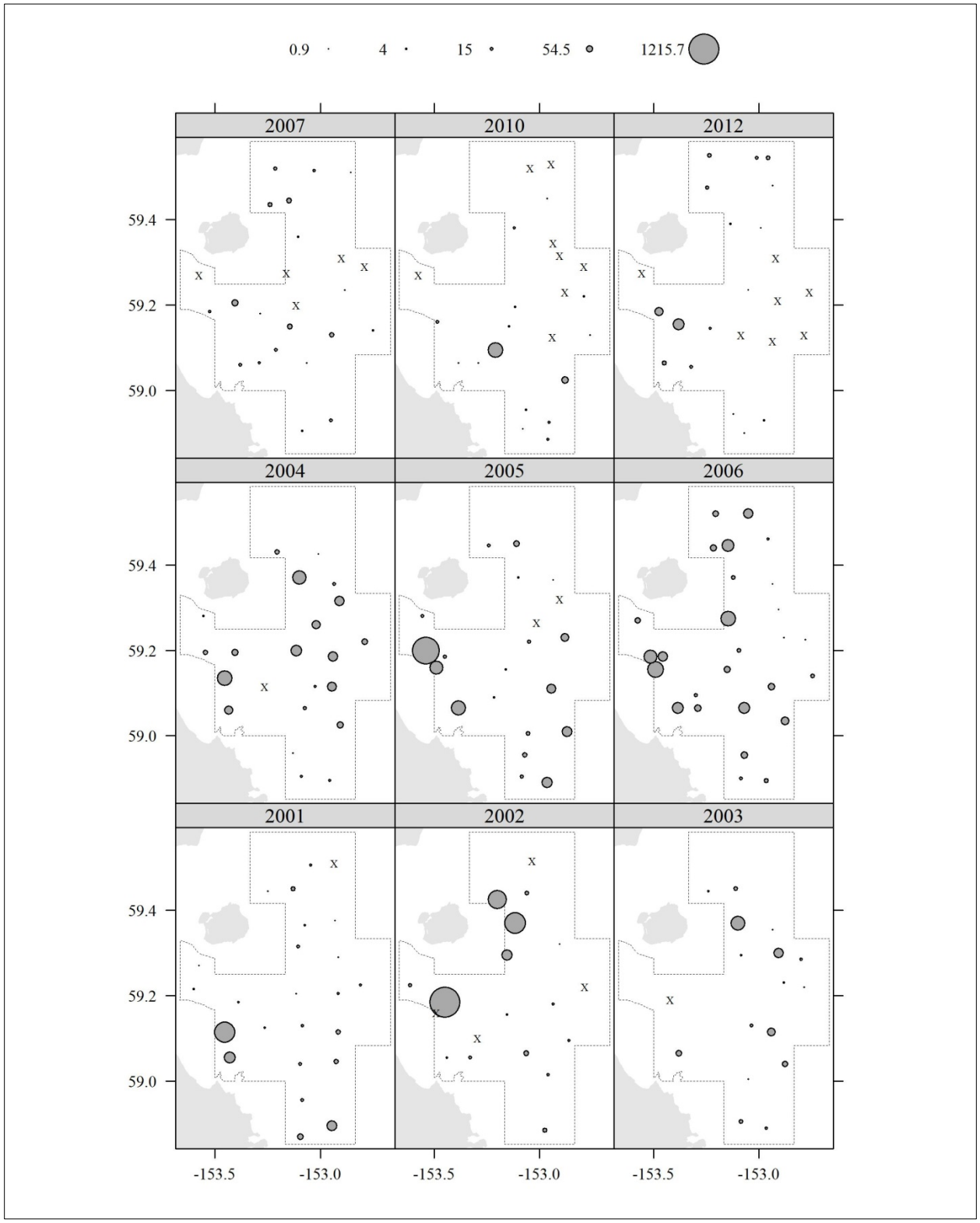
Appendix C4.–Geographic distribution of standardized catch of immature female Tanner crab in the Southern District, 2001–2013.



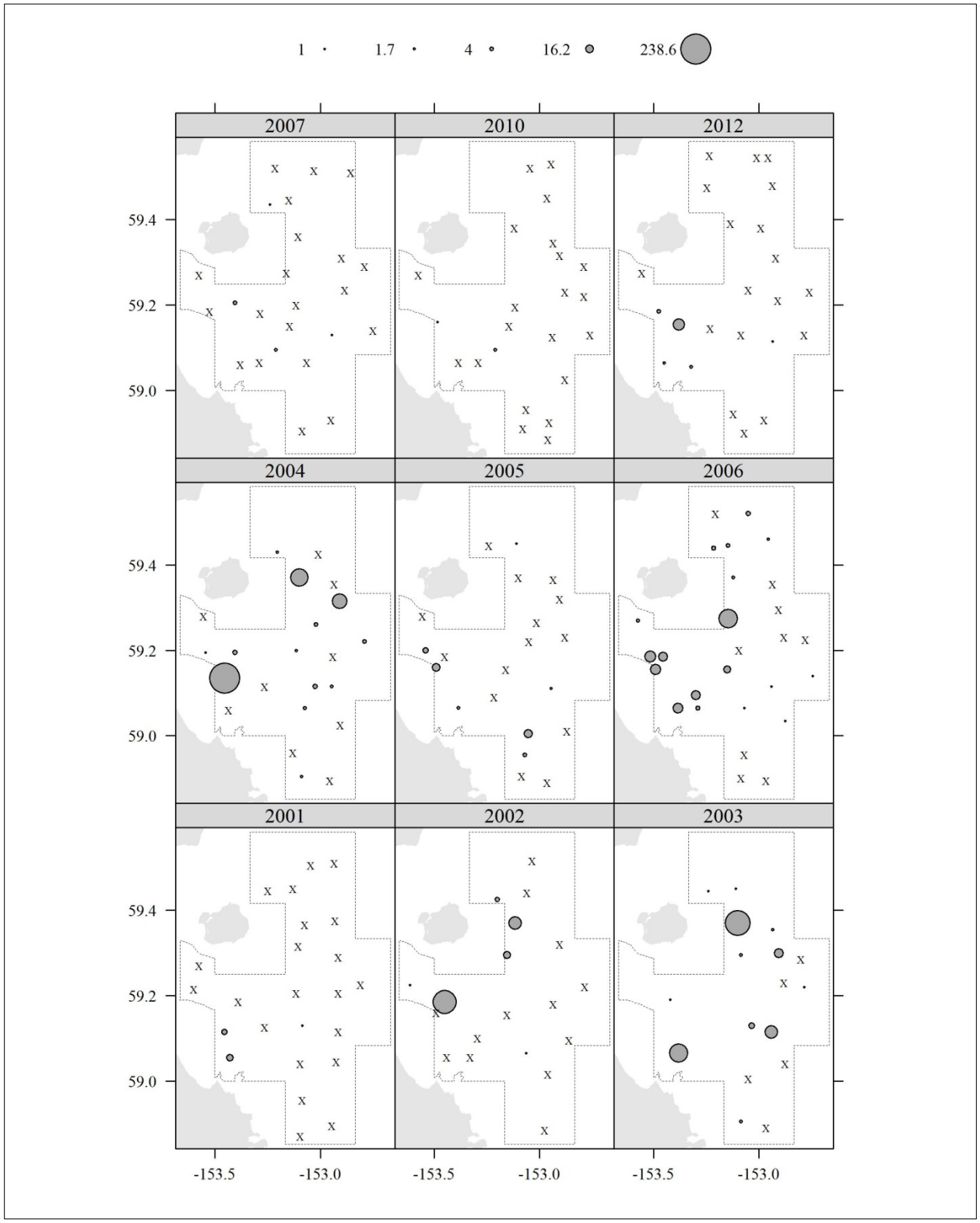
Appendix C5.–Geographic distribution of standardized catch of legal male Tanner crab in the Kamishak Bay and Barren Islands Districts, 2001–2012.



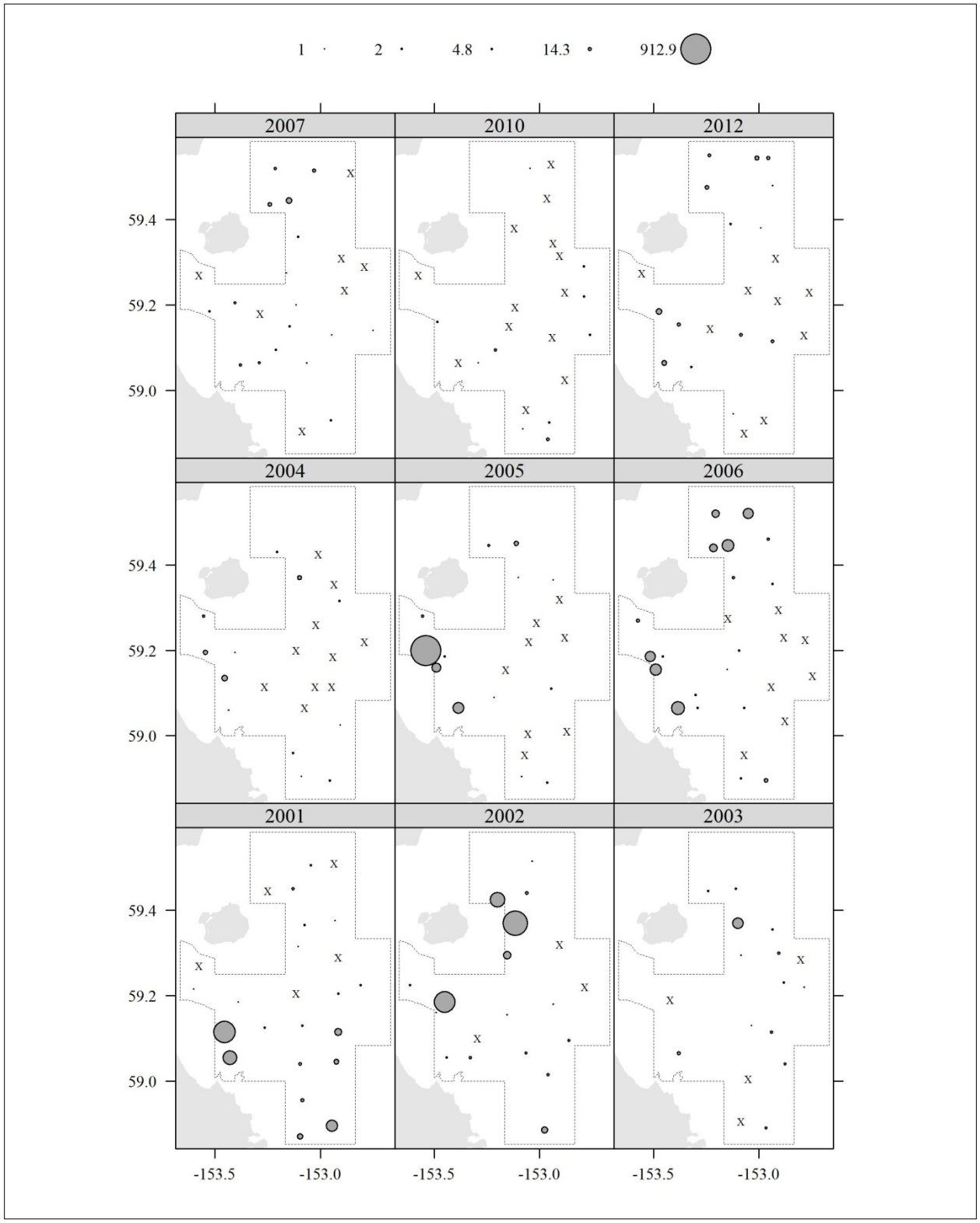
Appendix C6.–Geographic distribution of standardized catch of sublegal male Tanner crab in the Kamishak Bay and Barren Islands Districts, 2001–2012.



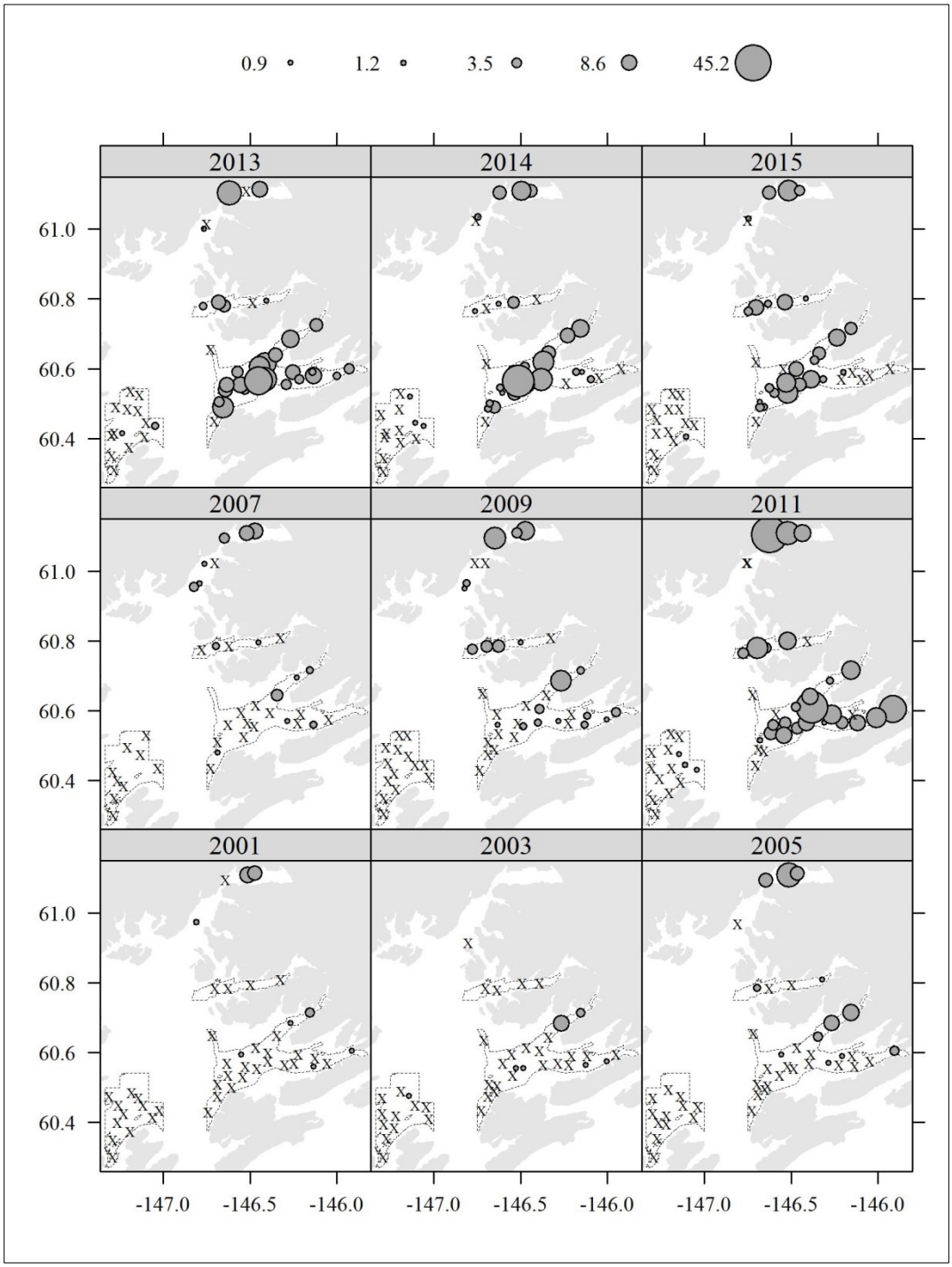
Appendix C7.–Geographic distribution of standardized catch of mature female Tanner crab in the Kamishak Bay and Barren Islands Districts, 2001–2012.



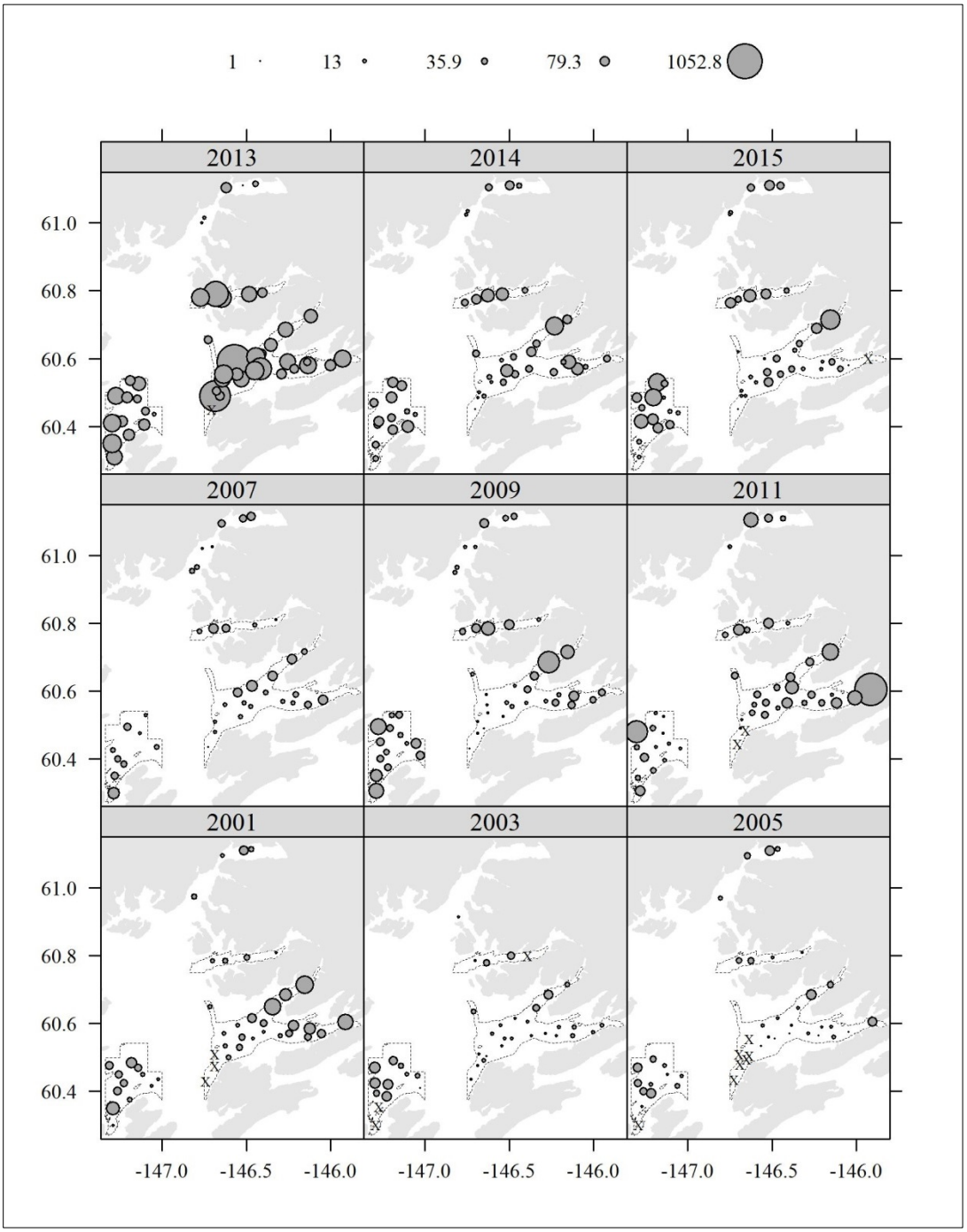
Appendix C8.–Geographic distribution of standardized catch of immature female Tanner crab in the Kamishak Bay and Barren Islands Districts, 2001–2012.



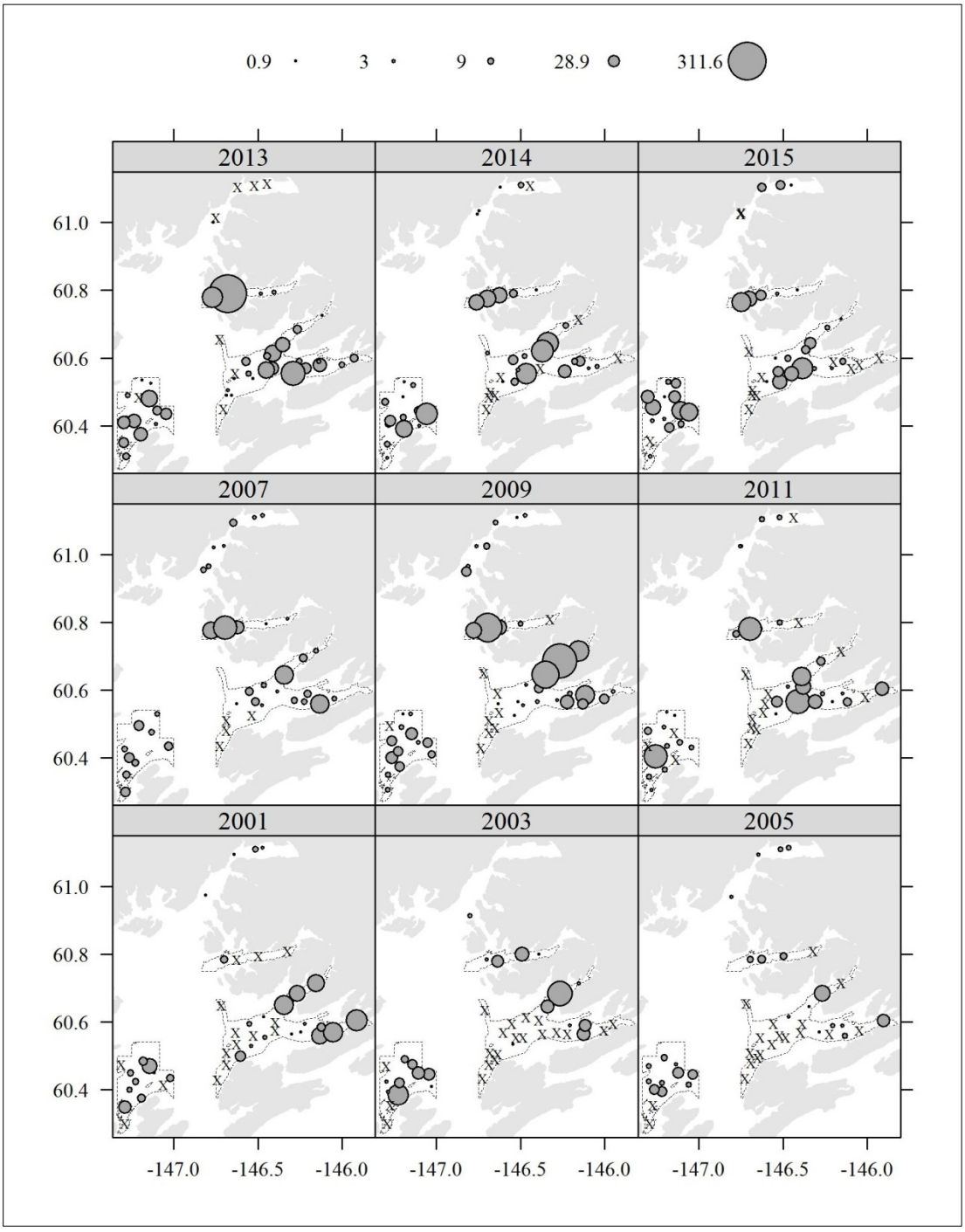
Appendix C9.–Geographic distribution of standardized catch of legal male Tanner crab in the Prince William Sound Management Area, 2001–2015.



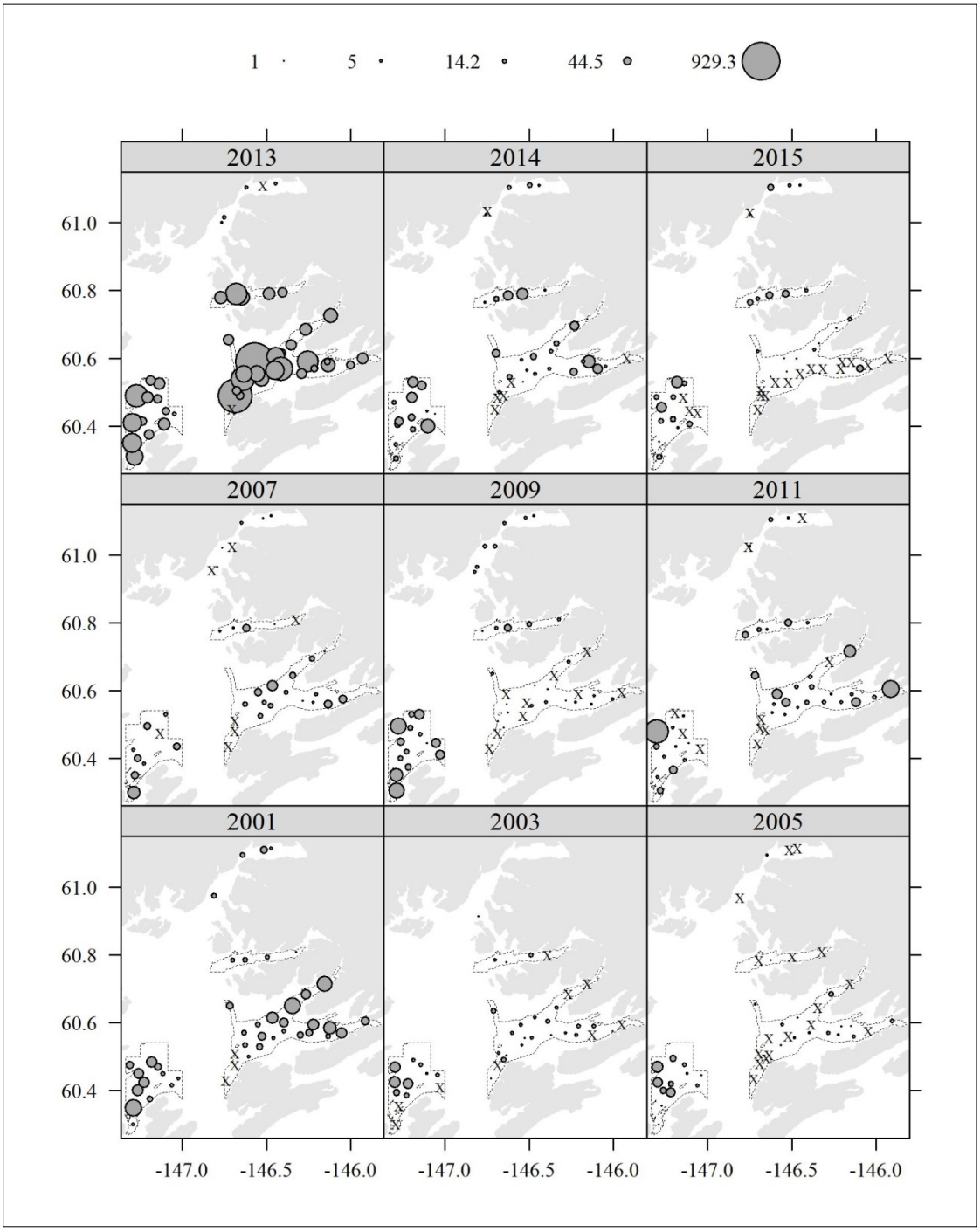
Appendix C10.–Geographic distribution of standardized catch of sublegal male Tanner crab in the Prince William Sound Management Area, 2001–2015.



Appendix C11.–Geographic distribution of standardized catch of mature female Tanner crab in the Prince William Sound Management Area, 2001–2015.



Appendix C12.–Geographic distribution of standardized catch of immature female Tanner crab in the Prince William Sound Management Area, 2001–2015.



APPENDIX D: NEW-SHELL AND OLD-SHELL ABUNDANCE ESTIMATES FOR MALE TANNER CRAB BY RECRUIT CATEGORY

Appendix D1.–Abundance estimates (thousands) for all male recruit categories with new- and old-shell broken out for pre-recruit 2 and larger crab with confidence intervals for all recruit groups in the Southern District, 1990–2013.

					Pre-recruit 2				Pre-recruit 1				Recruit				Post-recruit			
	05		Pre-recruit 3		New		Old		New		Old		New		Old		New		Old	
Year	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI
1990	496.7	322.4	722.9	462.3	603.6	334.5	10.4	8.1	451.9	273.8	40.8	24.8	145.2	90.0	173.0	258.6	12.3	11.0	57.9	98.7
1991	293.9	301.3	277.6	199.5	769.9	332.3	32.9	25.9	738.7	289.9	109.4	81.3	262.2	167.0	172.8	147.2	42.8	24.4	22.1	21.6
1992	237.2	193.5	125.0	65.6	420.6	232.1	34.5	28.9	699.4	380.1	203.1	217.9	841.9	637.3	134.0	166.3	54.5	37.3	25.4	36.4
1993	578.3	342.4	90.0	45.8	122.6	63.9	12.6	9.2	219.5	81.1	106.0	88.7	277.4	132.1	182.5	194.6	41.9	24.0	16.7	18.2
1994	312.3	238.9	210.1	116.4	123.7	54.2	9.1	7.7	96.0	48.7	62.6	42.3	67.5	42.3	97.2	84.9	6.8	8.4	21.8	20.1
1995	356.1	250.2	389.8	270.1	547.1	497.6	18.6	14.6	466.3	498.9	40.0	30.8	187.9	227.2	72.9	88.0	7.6	10.5	10.0	14.1
1996	186.4	145.6	44.6	41.1	370.6	504.1	152.3	136.8	418.5	452.7	182.5	131.7	52.1	35.9	49.2	41.4	0.0	0.0	0.0	0.0
1997	171.9	94.9	123.2	56.4	280.4	115.6	7.3	7.1	286.7	142.7	39.2	22.4	131.1	78.2	11.3	8.3	0.7	1.5	0.0	0.0
1998	325.5	246.5	19.2	14.9	13.0	11.0	11.0	8.1	126.6	117.7	68.4	85.1	128.9	105.6	70.8	120.0	6.1	8.2	0.0	0.0
1999	911.5	1,053.3	1,160.3	1,307.9	611.1	484.0	86.5	47.4	119.8	104.3	80.8	105.4	60.1	61.5	41.8	63.5	0.9	1.8	1.5	3.3
2000	513.4	484.6	453.6	385.3	374.1	245.0	16.9	9.2	367.9	193.5	12.7	10.8	72.4	62.3	8.5	8.2	0.0	0.0	1.6	3.3
2001	1,620.0	1,424.8	655.7	651.7	295.4	233.1	23.7	19.8	291.5	245.3	101.0	121.3	71.1	58.8	24.3	29.4	0.0	0.0	1.5	3.3
2002	2,027.6	1,530.1	1,275.5	909.0	470.7	320.5	28.9	26.4	193.7	166.6	17.3	14.7	86.2	69.9	1.8	2.6	0.0	0.0	0.0	0.0
2003	1,228.4	785.7	1,188.6	765.4	671.4	346.5	38.8	24.8	269.6	144.6	19.3	12.5	37.3	38.1	11.4	15.8	0.0	0.0	0.0	0.0
2004	671.5	383.1	1,119.2	815.6	952.9	609.0	84.8	92.6	567.2	355.6	116.7	138.2	85.1	73.0	25.8	39.6	0.0	0.0	0.0	0.0
2005	1,043.7	883.6	186.0	185.6	97.4	72.8	89.6	100.4	173.3	132.4	174.0	289.3	27.6	13.7	18.1	33.5	0.0	0.0	0.0	0.0
2006	1,029.6	1,391.9	154.7	228.0	186.7	238.0	43.4	34.9	183.9	273.5	42.5	62.1	200.2	262.7	24.3	35.4	0.0	0.0	0.0	0.0
2007	339.5	226.6	92.7	118.2	148.0	269.5	28.1	46.5	278.5	481.1	94.5	152.2	46.0	70.4	115.7	191.1	0.8	1.6	0.0	0.0
2008	552.3	383.8	224.9	374.6	96.1	91.5	63.1	75.2	141.2	121.4	98.5	186.2	62.6	57.1	40.2	73.5	2.7	5.7	0.0	0.0
2009	1,000.6	767.8	643.3	644.8	798.4	672.2	54.1	44.2	422.4	378.5	132.4	151.5	106.9	141.8	37.0	50.0	0.0	0.0	0.0	0.0
2010		NS																		
2011	4,109.5	1,938.5	159.3	97.8	16.2	16.3	24.1	15.2	9.7	12.4	85.1	81.4	12.5	21.6	30.1	35.7	0.0	0.0	0.0	0.0
2012	2,031.2	742.4	2,532.1	1,241.9	170.0	74.2	18.3	14.4	4.6	5.0	52.5	36.0	0.0	0.0	20.5	20.1	0.0	0.0	0.0	0.0
2013	925.7	412.5	680.7	260.0	1,300.2	533.3	90.4	68.6	74.8	38.2	66.4	62.1	1.9	2.7	33.6	31.6	0.0	0.0	2.6	4.2

Note: NS is no survey; CI is 95% confidence interval.

Appendix D2.–Abundance estimates (thousands) for all male recruit categories with new- and old-shell broken out for pre-recruit 2 and larger crab with confidence intervals for all recruit groups in the Kamishak and Barren Islands Districts, 1990–2012.

					Pre-recruit 2				Pre-recruit 1				Recruit				Post-recruit			
	Pre-recruit 4		Pre-recruit 3		New		Old		New		Old		New		Old		New		Old	
Year	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI
1990	496.7	322.4	722.9	462.3	603.6	334.5	10.4	8.1	451.9	273.8	40.8	24.8	145.2	90.0	173.0	258.6	12.3	11.0	57.9	98.7
1991	293.9	301.3	277.6	199.5	769.9	332.3	32.9	25.9	738.7	289.9	109.4	81.3	262.2	167.0	172.8	147.2	42.8	24.4	22.1	21.6
1992	237.2	193.5	125.0	65.6	420.6	232.1	34.5	28.9	699.4	380.1	203.1	217.9	841.9	637.3	134.0	166.3	54.5	37.3	25.4	36.4
1993	578.3	342.4	90.0	45.8	122.6	63.9	12.6	9.2	219.5	81.1	106.0	88.7	277.4	132.1	182.5	194.6	41.9	24.0	16.7	18.2
1994	312.3	238.9	210.1	116.4	123.7	54.2	9.1	7.7	96.0	48.7	62.6	42.3	67.5	42.3	97.2	84.9	6.8	8.4	21.8	20.1
1995	356.1	250.2	389.8	270.1	547.1	497.6	18.6	14.6	466.3	498.9	40.0	30.8	187.9	227.2	72.9	88.0	7.6	10.5	10.0	14.1
1996	186.4	145.6	44.6	41.1	370.6	504.1	152.3	136.8	418.5	452.7	182.5	131.7	52.1	35.9	49.2	41.4	0.0	0.0	0.0	0.0
1997	171.9	94.9	123.2	56.4	280.4	115.6	7.3	7.1	286.7	142.7	39.2	22.4	131.1	78.2	11.3	8.3	0.7	1.5	0.0	0.0
1998	325.5	246.5	19.2	14.9	13.0	11.0	11.0	8.1	126.6	117.7	68.4	85.1	128.9	105.6	70.8	120.0	6.1	8.2	0.0	0.0
1999	911.5	1,053.3	1,160.3	1,307.9	611.1	484.0	86.5	47.4	119.8	104.3	80.8	105.4	60.1	61.5	41.8	63.5	0.9	1.8	1.5	3.3
2000	513.4	484.6	453.6	385.3	374.1	245.0	16.9	9.2	367.9	193.5	12.7	10.8	72.4	62.3	8.5	8.2	0.0	0.0	1.6	3.3
2001	1,620.0	1,424.8	655.7	651.7	295.4	233.1	23.7	19.8	291.5	245.3	101.0	121.3	71.1	58.8	24.3	29.4	0.0	0.0	1.5	3.3
2002	2,027.6	1,530.1	1,275.5	909.0	470.7	320.5	28.9	26.4	193.7	166.6	17.3	14.7	86.2	69.9	1.8	2.6	0.0	0.0	0.0	0.0
2003	1,228.4	785.7	1,188.6	765.4	671.4	346.5	38.8	24.8	269.6	144.6	19.3	12.5	37.3	38.1	11.4	15.8	0.0	0.0	0.0	0.0
2004	671.5	383.1	1,119.2	815.6	952.9	609.0	84.8	92.6	567.2	355.6	116.7	138.2	85.1	73.0	25.8	39.6	0.0	0.0	0.0	0.0
2005	1,043.7	883.6	186.0	185.6	97.4	72.8	89.6	100.4	173.3	132.4	174.0	289.3	27.6	13.7	18.1	33.5	0.0	0.0	0.0	0.0
2006	1,029.6	1,391.9	154.7	228.0	186.7	238.0	43.4	34.9	183.9	273.5	42.5	62.1	200.2	262.7	24.3	35.4	0.0	0.0	0.0	0.0
2007	339.5	226.6	92.7	118.2	148.0	269.5	28.1	46.5	278.5	481.1	94.5	152.2	46.0	70.4	115.7	191.1	0.8	1.6	0.0	0.0
2008	552.3	383.8	224.9	374.6	96.1	91.5	63.1	75.2	141.2	121.4	98.5	186.2	62.6	57.1	40.2	73.5	2.7	5.7	0.0	0.0
2009	1,000.6	767.8	643.3	644.8	798.4	672.2	54.1	44.2	422.4	378.5	132.4	151.5	106.9	141.8	37.0	50.0	0.0	0.0	0.0	0.0
2010		NS																		
2011	4,109.5	1,938.5	159.3	97.8	16.2	16.3	24.1	15.2	9.7	12.4	85.1	81.4	12.5	21.6	30.1	35.7	0.0	0.0	0.0	0.0
2012	2,031.2	742.4	2,532.1	1,241.9	170.0	74.2	18.3	14.4	4.6	5.0	52.5	36.0	0.0	0.0	20.5	20.1	0.0	0.0	0.0	0.0
2013	925.7	412.5	680.7	260.0	1,300.2	533.3	90.4	68.6	74.8	38.2	66.4	62.1	1.9	2.7	33.6	31.6	0.0	0.0	2.6	4.2

Note: NS is no survey; CI is 95% confidence interval.

Appendix D3.–Abundance estimates (thousands) for all male recruit categories with new- and old-shell broken out for pre-recruit 2 and larger crab with confidence intervals for all recruit groups in the Prince William Sound Management Area.

					Pre-recruit 2				Pre-recruit 1				Recruit				Post recruit			
	Pre-recruit 4		Pre-recruit 3		New		Old		New		Old		New		Old		New		Old	
Year	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI	Abun.	±CI
1991	832.4	497.1	697.8	618.3	275.9	255.7	50.8	24.7	95.2	101.3	180.3	100.1	27.4	33.5	102.3	94.8	1.2	2.6	3.9	5.8
1992	601.9	185.9	320.0	275.6	392.7	249.4	94.8	45.0	153.5	65.9	164.5	70.5	10.0	8.0	55.1	37.4	1.1	2.2	2.0	2.8
1993	470.9	252.1	118.9	90.2	118.6	62.7	108.1	45.1	121.0	62.2	145.1	50.2	63.9	30.8	54.4	24.1	0.0	0.0	2.9	4.3
1994	669.3	435.3	79.7	50.4	34.4	23.7	89.0	34.1	21.1	13.0	161.5	61.3	5.0	7.2	49.6	23.4	0.0	0.0	1.0	2.0
1995	294.1	145.6	41.3	26.1	19.4	17.0	52.4	22.2	6.7	6.1	94.1	45.7	0.0	0.0	24.8	15.5	0.0	0.0	0.0	0.0
1996		NS																		
1997	209.7	120.8	56.0	34.2	34.7	16.3	16.4	9.8	10.4	6.7	23.9	20.7	1.9	2.7	9.4	8.6	0.0	0.0	0.0	0.0
1998		NS																		
1999	117.0	53.2	7.7	6.4	2.9	3.3	24.6	12.3	1.0	2.0	15.8	11.1	0.0	0.0	2.7	3.1	0.0	0.0	0.9	1.9
2000		NS																		
2001	1,364.1	476.4	407.2	239.3	180.6	148.8	42.5	24.0	30.3	24.0	28.8	17.0	3.8	6.0	2.9	3.2	0.0	0.0	0.0	0.0
2002		NS																		
2003	495.3	278.5	113.4	60.8	99.5	60.6	96.4	57.6	38.3	29.3	56.4	58.1	5.6	6.3	10.3	17.2	0.0	0.0	0.0	0.0
2004		NS																		
2005	279.7	176.0	80.6	57.5	82.1	65.1	60.5	50.4	50.1	38.6	67.3	50.7	17.9	15.9	10.1	13.4	0.9	1.9	0.0	0.0
2006		NS																		
2007	747.4	329.9	201.8	74.2	120.2	66.3	99.6	38.5	118.7	70.3	107.2	75.4	7.1	6.4	10.7	13.1	0.0	0.0	0.0	0.0
2008		NS																		
2009	1,009.7	506.8	509.0	357.4	190.0	87.9	66.5	25.7	235.8	118.4	101.3	43.2	33.6	22.8	10.3	9.0	0.0	0.0	0.0	0.0
2010		NS																		
2011	984.6	711.8	403.8	479.7	465.7	619.0	72.0	29.9	426.6	364.1	148.2	65.9	88.2	51.0	98.2	65.7	0.0	0.0	0.0	0.0
2012		NS																		
2013	5,986.8	2,223.4	1,024.7	511.0	358.6	139.1	70.6	26.2	134.4	52.8	187.8	82.0	56.9	28.0	121.2	54.0	0.9	1.8	6.0	5.4
2014	817.8	314.0	634.5	328.9	358.4	138.8	62.6	27.6	196.2	86.8	133.2	56.2	50.3	37.2	77.0	47.5	4.1	5.7	3.6	3.5
2015	611.0	383.3	466.3	343.0	567.5	303.0	42.0	29.4	229.3	83.7	73.0	34.6	57.4	30.9	41.9	22.1	3.5	3.4	0.0	0.0

Note: NS is no survey; CI is 95% confidence interval.

APPENDIX E: CLUTCH FULLNESS DATA FROM FEMALE TANNER CRAB

Appendix E1.–Clutch fullness of mature female Tanner crab caught in Central Region bottom trawl surveys, 1990–2015.

	Southern District				Kamishak and Barren Islands Districts				Prince William Sound			
Year	*n*	Barren	Partial	Full	*n*	Barren	Partial	Full	*n*	Barren	Partial	Full
1990	460	10.4%	14.1%	75.4%	127	4.7%	15.7%	79.5%	–	–	–	–
1991	1048	1.6%	3.8%	94.6%	21	4.8%	14.3%	81.0%	503	1.8%	38.0%	60.2%
1992	387	2.8%	5.2%	92.0%	55	0.0%	3.6%	96.4%	859	1.4%	13.2%	85.4%
1993	432	0.9%	9.3%	89.8%	210	0.0%	0.0%	100.0%	317	0.6%	9.8%	89.6%
1994	513	1.4%	6.0%	92.6%	240	0.4%	2.1%	97.5%	221	2.7%	9.5%	87.8%
1995	299	1.7%	4.3%	94.0%	123	0.0%	0.0%	100.0%	85	8.2%	25.9%	65.9%
1996	633	1.1%	29.1%	69.8%	38	2.6%	7.9%	89.5%				NS
1997	406	0.7%	24.6%	74.6%	20	5.0%	25.0%	70.0%	106	3.8%	30.2%	66.0%
1998	99	1.0%	30.3%	68.7%	2	0.0%	50.0%	50.0%				NS
1999	696	0.4%	24.3%	75.3%	11	0.0%	9.1%	90.9%	49	0.0%	24.5%	75.5%
2000	327	0.3%	19.9%	79.8%	1	0.0%	100.0%	0.0%				NS
2001	588	1.4%	14.6%	84.0%	21	4.8%	19.0%	76.2%	674	5.2%	30.4%	64.4%
2002	428	0.5%	16.8%	82.7%	212	2.8%	17.9%	79.2%				NS
2003	280	0.7%	11.1%	88.2%	335	0.0%	11.9%	88.1%	552	0.9%	7.6%	91.5%
2004	832	4.1%	16.1%	79.8%	360	0.0%	10.0%	90.0%				NS
2005	219	0.0%	36.1%	63.9%	50	0.0%	34.0%	66.0%	291	2.7%	38.8%	58.4%
2006	35	0.0%	45.7%	54.3%	264	12.9%	64.8%	22.3%				NS
2007	110	0.0%	44.5%	55.5%	9	11.1%	55.6%	33.3%	473	2.1%	45.5%	52.4%
2008	125	1.6%	25.6%	72.8%				NS				NS
2009	899	4.3%	46.6%	49.1%				NS	522	1.9%	22.6%	75.5%
2010		No survey			4	0.0%	50.0%	50.0%				NS
2011	397	1.8%	21.4%	76.8%				NS	680	1.9%	22.8%	75.3%
2012	566	2.7%	83.2%	14.1%	46	2.2%	30.4%	67.4%		No survey		
2013	1353	0.6%	69.6%	29.8%				NS	954	2.2%	61.4%	36.4%
2014				NS				NS	872	2.4%	55.2%	42.4%
2015				NS				NS	824	1.6%	27.4%	71.0%

APPENDIX F: TANNER CRAB TRAWL SURVEY DATA FROM ANCILLARY STATIONS IN THE VALDEZ AREA

Appendix F1.–Abundance estimates for male Tanner crab from ancillary bottom trawl surveys in the Valdez Arm of the Prince William Sound Management Area, 1999–2015.

		Number of sublegal males by pre-recruit size (CW)				Legal males			
Year	Tows	<73 mm	73–92 mm	93–112 mm	113–134 mm	>135 mm	±CI	Total males	Total ±CI
1999	4	1,463	0	4,684	11,274	22,163	21,000	39,583	37,525
2000		NS							
2001	4	109,773	20,244	7,255	12,990	25,852	42,158	176,114	186,362
2002		NS							
2003[a]	1	–	–	–	–	–	–	–	–
2004		NS							
2005	4	12,960	14,394	43,269	60,472	50,481	80,221	181,576	180,302
2006		NS							
2007	7	18,369	17,484	41,431	53,740	21,654	18,868	152,679	102,003
2008		NS							
2009	7	31,585	18,626	21,776	37,738	30,201	36,304	139,926	86,926
2010		NS							
2011	5	16,694	49,096	32,495	60,549	86,682	134,802	245,516	409,752
2012		NS							
2013	5	31,303	18,635	15,722	31,423	36,402	66,403	133,485	223,501
2014	5	53,390	21,641	26,249	23,819	31,741	37,677	156,840	161,911
2015	5	48,123	54,094	46,685	37,978	31,406	44,898	218,284	195,568

Note: NS is No survey; CW is carapace width; CI is 95% confidence interval.

[a] Insufficient sample size.

Appendix F2.–Standardized catch per unit effort (CPUE; crab per nautical mile) of male Tanner crab from ancillary bottom trawl surveys in the Valdez Arm of the Prince William Sound Management Area, 1999–2015.

		Number of sublegal males by pre-recruit size (CW)				Legal males			
Year	Tows	<73 mm	73–92 mm	93–112 mm	113–134 mm	>135 mm	Legal SD	Total	Total SD
1999	4	0.3	0.0	0.8	1.9	3.8	2.3	6.8	4.1
2000		NS							
2001	4	19.0	3.5	1.3	2.2	4.5	4.6	30.4	20.2
2002		NS							
2003[a]	1	–	–	–	–	–	–	–	–
2004		NS							
2005	4	2.2	2.5	7.5	10.4	8.7	8.7	31.3	19.6
2006		NS							
2007	7	3.2	3.0	7.2	9.3	3.7	3.5	26.4	19.1
2008		NS							
2009	7	5.5	3.2	3.8	6.5	5.2	6.8	24.2	16.2
2010		NS							
2011	5	2.9	8.5	5.6	10.5	15.0	18.8	42.4	57.0
2012		NS							
2013	5	5.4	3.2	2.7	5.4	6.3	9.2	23.0	31.1
2014	5	9.2	3.7	4.5	4.1	5.5	5.2	27.1	22.5
2015	5	8.3	9.3	8.1	6.6	5.4	6.2	37.7	27.2

Note: NS is no survey; CW is carapace width; CI is 95% confidence interval; SD is standard deviation.

[a] Insufficient sample size.

APPENDIX G: DUNGENESS AND RED KING CRAB CATCHES FROM BOTOM TRAWL SURVEYS

Appendix G1.–Catch per unit effort (CPUE) of Dungeness crab (crab/nmi) in the Southern District, 1990–2013.

		Sublegal males		Legal males		Total males		Total females	
Year	Tows	CPUE	SD	CPUE	SD	CPUE	SD	CPUE	SD
1990	14	21.93	36.14	0.35	0.83	22.28	36.74	40.25	74.57
1991	15	12.00	17.05	2.83	4.86	14.83	21.66	23.63	39.31
1992	15	9.62	15.07	4.35	6.99	13.97	21.73	35.13	54.41
1993	16	4.21	8.89	4.85	8.12	9.06	16.59	26.69	87.50
1994	16	0.73	1.40	1.51	3.21	2.24	4.42	6.05	15.68
1995	16	9.06	23.48	0.54	1.03	9.60	23.65	6.05	8.58
1996	16	7.51	15.74	3.48	6.05	10.99	21.55	22.88	40.23
1997	16	1.54	3.29	0.55	1.31	2.10	3.70	5.30	11.16
1998	16	0.32	0.62	0.19	0.40	0.51	0.82	0.76	1.51
1999	16	0.38	0.88	0.62	2.01	1.00	2.73	1.48	2.97
2000	16	0.31	0.60	0.12	0.34	0.44	0.73	1.12	2.27
2001	16	33.17	84.55	0.31	0.60	33.48	84.95	41.34	134.83
2002	14	5.43	13.33	0.91	2.12	6.34	14.49	24.70	66.42
2003	16	11.54	20.29	0.56	1.08	12.10	21.15	17.28	38.52
2004	16	3.45	6.52	0.88	2.28	4.32	8.69	5.38	13.34
2005	15	2.45	3.50	0.86	1.48	3.31	4.37	2.69	7.80
2006	17	53.05	169.52	3.08	6.69	56.12	175.78	25.93	46.34
2007	16	7.97	11.82	1.07	1.86	9.04	12.75	27.22	57.72
2008	16	8.28	9.66	0.89	2.09	9.17	11.41	15.70	18.82
2009	15	0.73	1.79	0.00	0.00	0.73	1.79	0.20	0.56
2010	NS								
2011	37	0.05	0.31	0.04	0.27	0.10	0.41	0.10	0.42
2012	37	0.25	0.90	0.00	0.00	0.25	0.90	0.06	0.35
2013	37	0.33	1.25	0.00	0.00	0.33	1.25	0.17	0.76

Note: NS is no survey; SD is standard deviation.

Appendix G2.–Catch per unit effort (CPUE) of Dungeness crab (crab/nmi) in the Kamishak and Barren Islands Districts, 1990–2012.

		Sublegal males		Legal males		Total males		Total females	
Year	Tows	CPUE	SD	CPUE	SD	CPUE	SD	CPUE	SD
1990	24	0.00	0.00	0.29	1.01	0.29	1.01	0.29	1.43
1991	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	24	0.04	0.20	0.00	0.00	0.04	0.20	0.00	0.00
2002	19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005	21	0.05	0.22	0.05	0.22	0.10	0.30	0.05	0.22
2006	27	1.31	4.64	0.00	0.00	1.31	4.64	0.44	1.95
2007	24	0.17	0.82	0.08	0.28	0.25	0.85	0.04	0.20
2008	NS								
2009	NS								
2010	23	0.13	0.46	0.00	0.00	0.13	0.46	0.00	0.00
2011	NS								
2012	23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: NS is no survey; SD is standard deviation.

Appendix G3.–Catch per unit effort (CPUE) of Dungeness crab (crab/nmi) in the Prince William Sound Management Area, 1991–2015.

		Sublegal males		Legal males		Total males		Total females	
Year	Tows	CPUE	SD	CPUE	SD	CPUE	SD	CPUE	SD
1991	29	0.27	0.82	0.00	0.00	0.27	0.82	1.08	3.37
1992	37	0.11	0.50	0.00	0.00	0.11	0.50	0.52	1.84
1993	38	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.47
1994	38	0.03	0.17	0.00	0.00	0.03	0.17	0.38	2.37
1995	32	0.09	0.51	0.00	0.00	0.09	0.51	1.29	7.31
1996	NS								
1997	39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	NS								
1999	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	NS								
2001	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	NS								
2003	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	NS								
2005	40	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.22
2006	NS								
2007	32	0.03	0.18	0.00	0.00	0.03	0.18	0.03	0.18
2008	NS								
2009	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	NS								
2011	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	NS								
2013	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2014	41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: NS is no survey; SD is standard deviation.

Appendix G4.–Catch per unit effort (CPUE) of red king crab (crab/nmi) in the Southern District, 1990–2013.

		Sublegal males		Legal males		Total males		Total females	
Year	Tows	CPUE	SD	CPUE	SD	CPUE	SD	CPUE	SD
1990	14	0.07	0.26	0.24	0.49	0.31	0.65	0.14	0.53
1991	15	0.06	0.25	6.53	22.15	6.60	22.40	0.52	1.49
1992	15	0.27	0.71	3.13	6.16	3.40	6.50	5.50	18.14
1993	16	0.43	1.01	0.48	0.70	0.91	1.56	1.28	3.34
1994	16	0.24	0.73	0.42	0.71	0.66	1.08	0.58	2.34
1995	16	0.00	0.00	0.18	0.39	0.18	0.39	0.06	0.23
1996	16	0.06	0.26	0.24	0.74	0.30	0.76	0.12	0.34
1997	16	0.00	0.00	0.06	0.24	0.06	0.24	0.00	0.00
1998	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	16	0.00	0.00	0.13	0.36	0.13	0.36	0.00	0.00
2000	16	0.00	0.00	0.13	0.35	0.13	0.35	0.00	0.00
2001	16	0.00	0.00	0.25	1.00	0.25	1.00	0.00	0.00
2002	14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003	16	0.00	0.00	0.13	0.34	0.13	0.34	0.00	0.00
2004	16	0.00	0.00	0.18	0.70	0.18	0.70	0.00	0.00
2005	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2006	17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009	15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	NS								
2011	37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2013	37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: NS is no survey; SD is standard deviation.

Appendix G5.–Catch per unit effort (CPUE) of red king crab (crab/nmi) in the Kamishak and Barren Islands Districts. 1990–2012.

		Sublegal males		Legal males		Total males		Total females	
Year	Tows	CPUE	SD	CPUE	SD	CPUE	SD	CPUE	SD
1990	24	0.08	0.29	0.17	0.64	0.25	0.68	0.17	0.64
1991	17	0.00	0.00	0.47	0.79	0.47	0.79	0.00	0.00
1992	25	0.12	0.45	0.56	1.49	0.68	1.87	0.12	0.59
1993	15	0.07	0.26	0.07	0.26	0.13	0.35	0.00	0.00
1994	17	0.00	0.00	0.17	0.51	0.17	0.51	0.00	0.00
1995	24	0.12	0.44	0.12	0.44	0.25	0.73	0.18	0.42
1996	18	1.49	4.77	0.10	0.44	1.59	4.93	0.46	1.35
1997	18	2.29	5.60	0.73	2.22	3.01	7.19	3.57	10.54
1998	22	0.22	0.41	0.39	0.81	0.61	1.04	0.22	1.05
1999	19	0.00	0.00	0.11	0.33	0.11	0.33	0.00	0.00
2000	24	0.12	0.33	5.22	20.62	5.34	20.84	0.37	1.41
2001	24	0.00	0.00	3.27	8.28	3.27	8.28	2.21	10.61
2002	19	0.10	0.31	0.15	0.48	0.25	0.54	0.05	0.22
2003	17	0.00	0.00	0.18	0.53	0.18	0.53	0.00	0.00
2004	22	0.05	0.21	0.24	0.55	0.28	0.65	0.09	0.43
2005	21	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.36
2006	27	0.24	1.06	0.04	0.20	0.28	1.07	0.34	1.58
2007	24	0.12	0.44	0.12	0.45	0.25	0.72	0.20	0.64
2008	NS								
2009	NS								
2010	23	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.21
2011	NS								
2012	23	0.09	0.41	0.00	0.00	0.09	0.41	0.00	0.00

Note: NS is no survey; SD is standard deviation.

Appendix G6.–Catch per unit effort (CPUE) of red king crab (crab/nmi) in the Prince William Sound Management Area. 1991–2015.

		Sublegal males		Legal males		Total males		Total females	
Year	Tows	CPUE	SD	CPUE	SD	CPUE	SD	CPUE	SD
1991	29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1992	37	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.31
1993	38	0.00	0.00	0.02	0.15	0.02	0.15	0.03	0.16
1994	38	0.03	0.16	0.00	0.00	0.03	0.16	0.03	0.16
1995	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1996	NS								
1997	39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998	NS								
1999	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	NS								
2001	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	NS								
2003	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2004	NS								
2005	40	0.02	0.16	0.00	0.00	0.02	0.16	0.00	0.00
2006	NS								
2007	32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	NS								
2009	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	NS								
2011	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2012	NS								
2013	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2014	41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: NS is no survey; SD is standard deviation.